Forecasting Model to Evaluate C&D Wastes by Maintenance and Refurbishment: The Case of Le Vallette

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Space for Living Streets of Wroclaw

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Abstract: From the very beginning the street was and still is essential for moving, living and participating in city life. At present we all struggle with communication, traffic and pollution. Now the streets have a different image of their own structure where the car has dominated its space. This research focuses on a bigger picture of the mobility in the city of Wroclaw. Twelve streets including market squares and public places were taken into consideration while providing necessary data for this research. It is very clear that a need of a public space is necessary for a quality of daily life. Also, considering a street as a part of this public space is the main point of my research where I would like to prove that giving the street its importance back, can greatly influence on the development of the urbanized space at the city. I will concentrate on the parts of the city centre of Wroclaw. The major question is how and if we can change and bring our streets back to life. If we can change this we will be able to give our streets deeper meaning in our lifestyle.

Key words: Public space, streets, mobility.

1. Introduction

From the beginning the street has been a link between different structures and areas building a coherent organism.

Today the image and appearance of the street is changing. It depends on many conditions, i.e.: social, geographical, historical, but also the vision of the city's governors or the main urban planner.

Without a street, it is difficult to imagine a functioning city. An area, without which we could not function and develop, where everyday life intertwines with different needs and activities, expressed through development, giving meaning, importance or prestige to the place. After all, it is also the most important element of access to one's own home.

In recent decades there has been a reflection not only on its perception, but also on its function, position, an important place in the structure of the city. The street, because it is often an ordinary transport route, where traffic flows, ceases to be a perceptible essential space in our everyday life. However, without a street, it is impossible to imagine functioning in everyday life. It is an important element in the life of every community.

For several decades it has been the subject of research, searches and problems in urban structures and beyond.

Also the streets of Wroclaw determine the history of this place, creating over the centuries the cultural richness of the city. This phenomenon is getting even more important today, after so many actions have already been taken to make a street a safe place, offering a possibility of interaction. It is a place of meetings, rest and activity. Streets are a space to live and for life. However, even today we have examples of emptying, abandonment of the street, its social and technical degradation, and devastation of districts or fragments of the city follows.

Many of the above mentioned reflections may not be answered today, but it is worth looking at these phenomena at least in a small part and asking questions about the future and the value of the space of Wroclaw's city streets.

This is the source of important problems for the author, i.e.: to examine the quality of the street space in Wroclaw, its attractiveness, but above all to draw

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attention to the value of this space as being important for and in the everyday life of the city.

In our culture, street and square are still the most important determinants of the composition of the city plan, and their character represents the cultural values with which the residents identify themselves. Polish urban planners, in the Charter of Public Space [1] emphasize the particular importance of the place for satisfying the needs of the local and supra-local community, pointing at the same time to the "collective way of using it". Together with architects, they perceive space in terms of functionality, drawing attention to its architectural and urban resources and values aimed at satisfying the needs and aspirations of the inhabitants.

By definition, which was included in the Charter of Public Space at the Third Congress of Urban Planning of the Polish Society of Polish Town Planners and the Union of Polish Cities in September 2009, space was recognized as a commonly used good, deliberately shaped by man, in accordance with social principles and values—serving the needs of local and supra-local communities, and the public character of space is determined by the collective use of it.

From this definition it is worth emphasizing the accessibility of space and its collective character of use.

Important activities conducive to the protection and rational use of public space were also selected, as laid down in the Charter of Public Space of the Third Congress of Polish Urban Planners, which include: Maximising the value of the city and its real estate by creating high quality public spaces.

- Comprehensive local planning and urban design of public spaces based on the results of urban and architectural competitions;
- Social participation in the creation of tools for shaping and managing public space, with the active participation of local communities in the process of preparing planning documents;
- Protection of cultural heritage and local specificity as special values of public spaces;
- Balance in creating a new public space in relation to the revitalized historical space;
- Fair access to public spaces and minimization of conflicts in their creation and use;
- Shaping public spaces integrating social groups with respect for their different needs and value systems;
- Active use of public spaces and their use for organizing local events [1].

However, the subject of urban space, and urban street in particular, began to gain importance in the literature of the subject, and in the 1960s, with the publication of the tractate by Jacobs [2] in 1964, the need to change the thinking of urban planners about urban space was highlighted more strongly, where the approach to date has been shown to be too disconnected from reality and the needs of the inhabitants.

According to Jacobs [2], plans or urban assumptions met the requirements of Table 1 which presents selected important problems for the development of urban thought in spatial planning.

Designers perceive the cities themselves as a living and constantly changing structure.

On the other hand, in the assumptions for the author's research on Wroclaw Streets, the main goal was to ensure, that the quality of urban street space was visible through the eyes of its inhabitant and to be closer in the future to the needs of the inhabitant, than just the vision of the development of a specific urban tissue resulting from the idea or concept of urban planners and territorial self-government units responsible for the development of the city.

And so that both residents and people responsible for spatial planning, when planning development, analyse the value of space from different perspectives: the obvious: historical or economic ones, but also sociological or psychological, which are gaining importance nowadays.

Table 1 Selected problems concerning public space.

Periods	Research topic	Authors	Main issues
60's	"The Death and Life of Great American Cities" (1961 r.)	Jane Jacobs	Problems of dying and running on empty streets and spaces in American cities [2].
70's	The Social Life of Small Urban Spaces	William Holly White	He started in his research looking for quality space for people. He inspired other people in the area of sociology as well as in urban planning to look for there [3]. Many projects implemented through the Project for Public Spaces organisation (PPS—was founded in 1975 and since then has been very active in the public-private partnership for the quality of public space).
	"Defensible Space" (1972)	Oscar Newman	Problematic safety of the space [4]. Neighbourhood area being controlled and protected by neighbours and making easier to recognize strangers and potential danger behaviours in the neighbourhood.
80's-2000's and now	Looking for links and understanding of space from different perspectives		Issues very often included in the current of environmental psychology—an interdisciplinary branch of science researching relations between man (his behaviours and feelings) and the environment.
	Internet, urban mobility and the space of streets and places		Activation of space.

Source: Own elaboration.

2. Selected Elements Concerning Perception of Streets

An important part of the research topic undertaken by the author is to broaden the perspective and quote the results of research conducted by SW Research for larger Polish cities, including Wroclaw. The research concerned the importance of the shopping street and its social and economic potential. Ref. [5] includes the results of consumer research conducted in terms of the perception of the concept of a shopping street and supply gaps.

The main four objectives of the report are to redefine the concept of a shopping street, to identify the role of this shopping street format in the development of Polish cities, to analyse the potential of shopping streets and the key factors influencing their development, and to present the strategy of the largest Polish urban centres for the development of shopping streets. The analysis included Warsaw, Krakow, Lodz, Wroclaw, Poznan, Tri-City, Szczecin and Katowice.

For the author the important results were those concerning time spent by residents on a shopping street and in a shopping centre (Fig. 1) [5].

The research involved such issues as preference of choice, realization of needs, satisfaction with the activity and interaction on the shopping street of the residents, compared to the shopping centre. The research has shown, among other things, that the percentage of residents spending over on hour on shopping streets was the highest in Lodz (55%) and the lowest result was observed among residents of Krakow (24%). In the case shopping malls the largest number of residents of Warsaw (82%) and Katowice (81%) spent more than an hour there, while the lowest result, recorded in the Tri-City, was 63%. An important element that emerges from this research is to maintain the attractiveness of the shopping streets compared to shopping centres.

Fig. 2 shows how and what elements can affect the importance of the shopping street and what kind of shopping centres are gaining importance today. Very important for a shopping street is its function related to prestige, uniqueness and atmosphere of the place. It is often the main shopping artery in the city, or an important element in the structure of the city of historical importance.

Other important elements are its equipment and

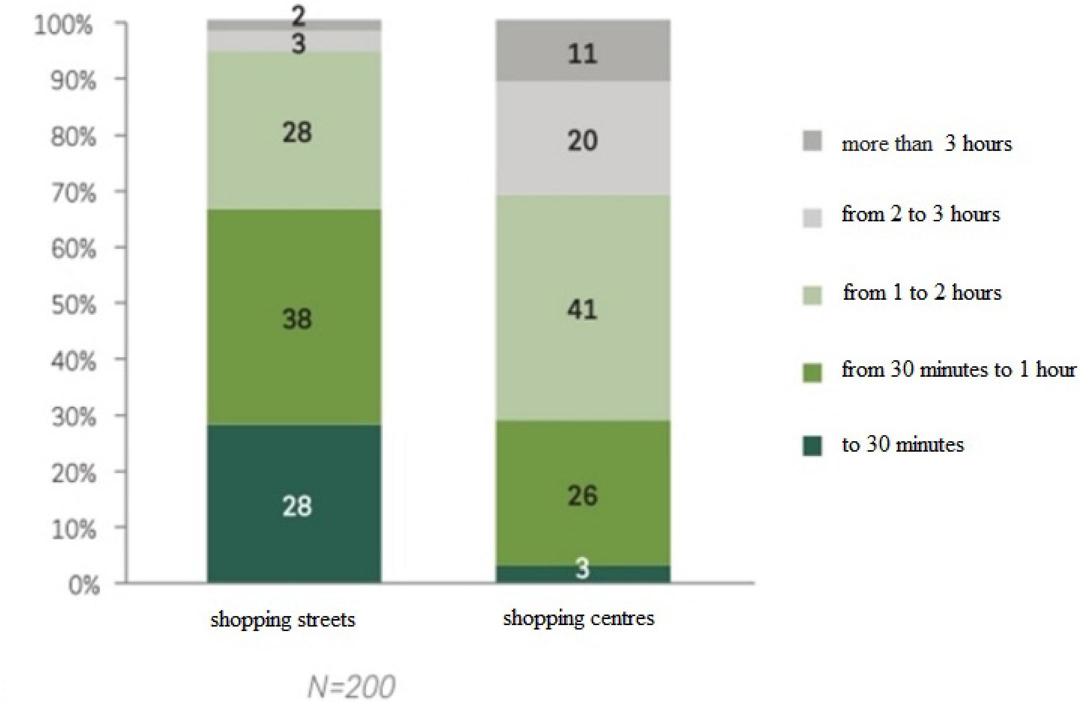

Fig. 1 The time spent by a resident on a shopping street and in a shopping centre in Wroclaw.
Source: Ref. [5].

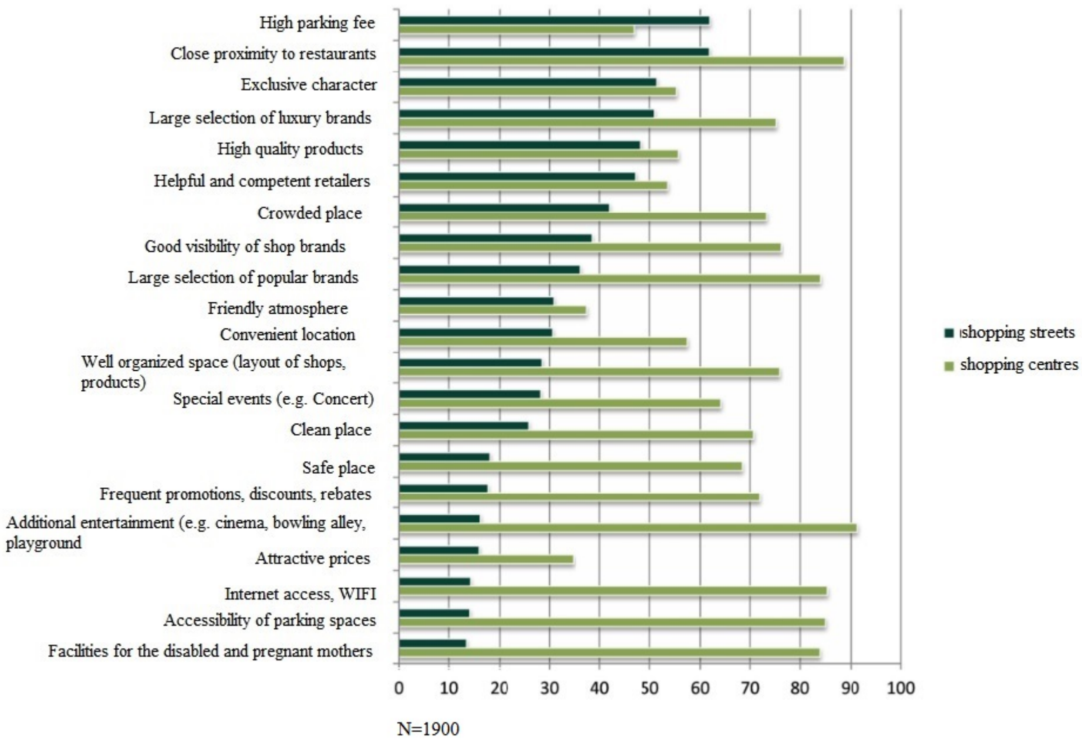

Fig. 2 The attractiveness of the shopping street compared to shopping centres.
Source: Ref. [5].

aesthetic and cultural values, as well as the high quality of services and products offered. Shopping centres evolve in the area of infrastructure, equipment with the latest technical facilities and accessibility related to parking spaces.

The conclusion to be drawn from this view is the fact that currently in the surveyed Polish cities a shopping street and a shopping centre, is an area of competition. It is worth emphasizing those elements that strengthen the importance of the shopping street (Fig. 2), i.e.: its openness to interactions and social, cultural values related to the identity, uniqueness of the place, and thus the identification of the residents themselves with the city street, which may affect the value of the space in the city.

The presented material is the first stage for further developed research on the potential and value of the city streets and their revitalisation. The article presents some selected conclusions to illustrate the importance of the topic.

The research concerns the area of the strict centre of Wroclaw and the city centre. It took two months—June-July 2017. The research involved interviews with 260 people on 12 streets, six squares and boulevards of Wroclaw (Fig. 3).

The research concerned the development of an appropriate questionnaire for the research. Questionnaire created for this research had been divided into four theme areas: perception of the street, street equipment, street programme, city furniture. The survey contained 24 questions. The most important concerned:

- Analysis of existing programs (events) on the streets of Wroclaw on selected examples, like St. Anthony’s Street, and others;
- Analysis of the needs of residents and the programs being carried out in selected locations indicated by the residents (in the survey);
- An indication of the specific streets recommended to change their current function and features (in the survey).

The research was inspired by the implementation of a project on St. Anthony’s Street (Fig. 4), which assumed the creation of high quality space for residents and tourists and the improvement of safety of pedestrians and cyclists in this place. The selected example of the street is important due to its close location and links to the oldest part of Wroclaw with the Market Square. It also creates a communication artery in the area which, as one of the first since 1995, is a place of meetings and cultural events important in the life of the city. By changing the organisation of

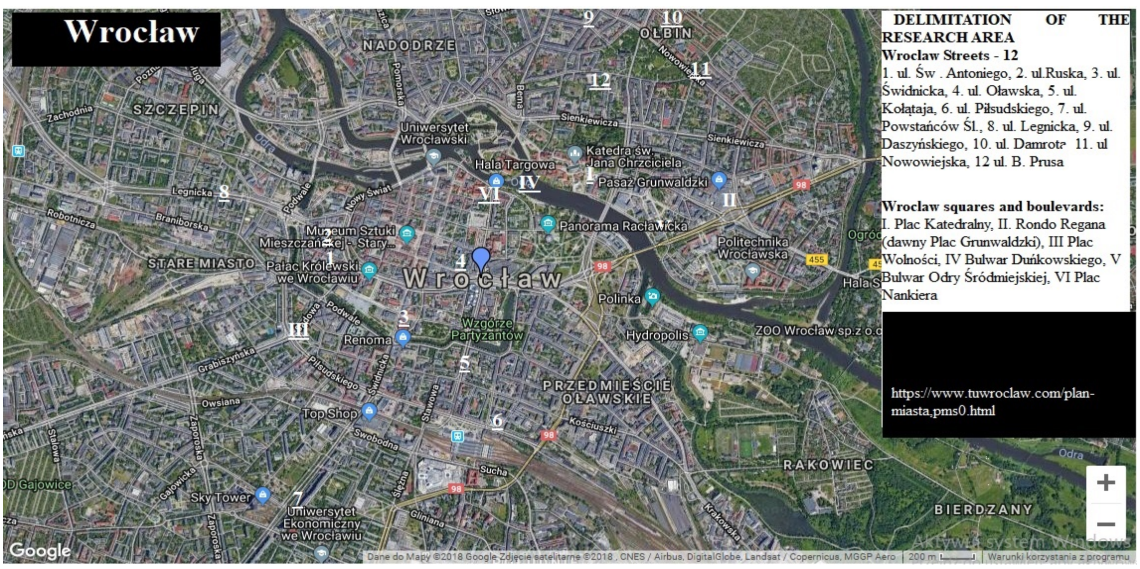

Fig. 3 The area of the strict centre of Wroclaw.
Source: Own elaboration.

Fig. 4 St. Anthony Street—the project first Woonerf in Wroclaw.
Source: https://www.radiowroclaw.pl/articles/view/50104/Wroclaw-Tak-ma-wygladac-ulica-sw-Antoniego-WIZUALIZACJE.

Fig. 5 St. Anthony Street in Wroclaw.
Source: Own elaboration.

traffic and improved equipment in space, St. Anthony's Street became the first Woonerf—the city courtyard.

The creators of the project proposed above all to calm down car traffic. In places where only cars were parked, so-called side islands were placed, i.e. platforms where elements of small architecture were installed (Fig. 5).

The research on St. Anthony Street confirms the need to undertake actions influencing the change of image and organisation of street space in cities. The effects achieved were due to the implementation of the assumptions of the change in the spatial organisation of St. Anthony Street.

From a crowded place filled with cars to a place where you can stop and spend some time. 60% of respondents stated, that the place is safe and there is a possibility of spending free time there.

The street and its surroundings gained both in the organisation of car traffic and other services such as catering, including restaurants and bars, or cafes and other cultural places were strengthened.

From the original research in the above mentioned area of the study, the results are that, however, the level of street safety is not sufficient—Wroclaw's streets are places perceived as dangerous.

Another important observation from the research on the Wroclaw Street is the lack of knowledge and awareness of residents about urban furniture. Most of the answers were limited to the respondents' indicating whether there was a need for lighting, space for bicycles or benches.

3. Conclusions

Through a preliminary analysis of the research undertaken by the author, the following conclusions can be drawn. There is a visible need to carry out this type of research in order to strengthen public awareness of the quality of the space and its value not only in cultural but also in social aspect, strengthening participation in the creation of public space development and the influence of a more conscious inhabitant on improving the quality of space in their place of residence.

Another conclusion is to strengthen the educational activities related to understanding of urban space, learning about its history, but also to broaden the knowledge of architecture, urban planning and social issues. This will make it possible to raise awareness on the knowledge of the city, tradition and culture. It will make it also possible to broaden the inhabitants' perception of the shared space as a value and potential for development.

Raising the awareness of both residents and city authorities about the quality of space, its cultural and social richness, and the knowledge of diversity will bring greater attention to space as a unique value—understood as a good place to live.

Let this quote be an inspiration to continue the path that began in the already mentioned 1960s and still exists. May a more conscious look at the street space contribute to the revival of the city space as a good place to live.

Good places should be created by people and for people. They should be valuable and worthwhile. They should also make people want to stay there come back to such a good place.

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Forecasting Model to Evaluate C&D Wastes by Maintenance and Refurbishment: The Case of Le Vallette

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Abstract: The urban regeneration lies on closed loops of energy, materials, information. The aim of case study is to evaluate and support policies of urban regeneration. The topic of the study is the control of waste flow made by the C&D (construction & demolition) activities involving the urban district. Each building produces a continuous flow of wastes during its predicted service life. This flow is mainly due to small building sites that generate small amount of wastes. In this way the collection, recycle and reuse material can be less accurate. In a regeneration perspective the reused and/or recycled part must be maximized. The study develops a GIS (geographic information system) based model for the assessment of the maintenance workloads of wastes produced. Coming from the data available by the public authorities and the survey on sites, the research group has carried out evaluation of the amount of wastes for building envelope, interior refurbishment of apartments, roads and parking lots. The output is a raw estimation of the C&D wastes by the maintenance and refurbishment of an urban district in Turin based on real evaluation of works needed.

Key words: Regeneration, maintenance, C&D wastes, building stock, urban metabolism.

1. Introduction

During the use phase of a building, it is necessary to put forward the disposal of construction products generated in the maintenance and refurbishment works. Such wastes, from small dismantling operations rather than from major works, contribute sensitively on total waste from C&D (construction & demolition). In Italy the C&D wastes are estimated to 48 million tons per year, i.e. 37.4% of total non-hazardous special waste [1]. According to the report Recycle, drafted by Legambiente, in Italy the production of C&D wastes is 0.8 tons per person, a lower result if compared with European average (1.09 tons per person). National and regional aggregate data do not allow to verify the real amount of C&D wastes.

In Europe, two legislative instruments manage and promote the proper disposal of waste including C&D: the European Directive 2008/98/EC and the European List of Waste 2000/532/EC. The former directive promotes the waste hierarchy through "a priority order in waste prevention and management legislation and policy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal" [2].

The study presented is referred to a large stock of residential buildings for which a maintenance/end of life scenario is not generally anticipated at the design stage.

The building stock is mainly managed by ATC (Agenzia Territoriale per la Casa), about 40% of the total in neighborhood Le Vallette in Turin. The maintenance and refurbishment of such a building stock requires a number of building sites established every year in the city area. In addition most of the buildings in that area can be considered heritage, the construction going back to the 1960s. The financial significance of such activities is evident as well as the environmental consequences in terms of emissions, wastes and energy consumption. In this perspective, good management of such works is very important. On one hand a good quality of buildings means a good quality of life for inhabitants. On the other hand an

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appropriate use and maintenance of the building stock affects the environment. In this way a good maintenance management by a big public housing agency can contribute to the urban regeneration. In other words durability of buildings and of its parts can affect in a substantial way the expenditures for maintenance as well as the environmental load in a substantial way.

2. Aim and Methodology

The aim of the research is to develop a user friendly method to forecast the amount of major maintenance works is needed and to assess the impact of such a work on the environment in terms of C&D wastes. In other words the goal of the research is the development of a tool to support decisions in maintenance and C&D waste management policies.

The method developed can help in an eco-efficient management of the waste generated in the use phase, e.g. the replacing of building elements, the refurbishment of an apartment etc.

This method is based on the following elements:

- a technological analysis of the building failures based on FMEA (failures modes and effects analysis) and on scientific literature focused on building pathology and defects;
- survey sheets to assess the degradation levels;
- building features data (height, surface, typology etc.) from GIS (geographic information system);
- algorithms to calculate the maintenance needed according to the results of the previous survey.

Interventions in terms of wastes produced are defined “a priori” in the FMEA (failure mode and effect analysis) carried out by the research group for each type of building. The priority for intervention as well as durability of the building parts can be considered as input of the model that can affect the output and scenarios. The study is based on a summary survey of buildings implemented by the research group.

This survey is aimed to detect degradation phenomena and collect data on the condition of the buildings. Survey sheets provide raw information on defects and failures of the main parts of the building fabric and fixtures. The different types of building elements and technologies have been considered in the development of survey sheets by the research team. The GIS is used to collect the data of buildings and to geo-reference them. Main features and data, such as elevation, perimeter, façade surface and roof area, are calculated directly from the GIS model implemented in this study by the research group. In this way a raw estimate of works is feasible without a detailed survey and building mapping.

According to the knowledge available and literature on building degradation processes the research develops an evaluation scheme of the causes and consequences of any failure detected by the appraisal of phenomena in terms of maintenance needs and wastes from demolition. Moreover the priority of the interventions for safety and impacts on building performances has been taken into account. In other words, priority and maintenance intervention are coupled to the effects, extension and level of degradation identified by the building managers in the survey. The building part breakdown is aimed to the detection of degradation phenomena and of maintenance works to keep the building systems fully functional. In addition, the identification of parts is useful to collect data for the characterization of the behavior over time. Moreover the comparison between the age of the buildings and parts and the levels of degradation represented by the phenomena described in the sheets will allow predictions about the need of maintenance operations in the future.

There are various levels of degradation of the building parts, depending on the consequences for the system in terms of deviations from the desired quality levels, corresponding to different interventions necessary to keep the desired standard. These four levels, corresponding to the priority of intervention, are:

Level 1. Failures affecting safety of the people;

Level 2. Major loss in functionality of the building (i.e.: increase in energy consumptions, degradation of other building elements by water penetration etc.);

Level 3. Loss of function of the single building element;

Level 4. Appearance of the building.

The assessment of a specific degradation level corresponds to a scenario of intervention. In such a scenario the quality level will be defined complying according to the agency policy, also in relation to the financial constraints. Different scenarios imply a quantity of wastes.

The calculation algorithm is based, therefore, on the following steps:

- Selection of the phenomena that present levels of degradation greater than or equal to the threshold identified “a priori” on the basis of the consequences and desired performance levels;
- Setting of intervention scenarios based on the predefined thresholds, made possible by the forecasting model;
- Updating of forecasts as a result of successive surveys and/or performing maintenance work of replacing parts that reset the age of the component to the time 0.

This approach would allow to refine the feedback coming to considering the peculiar features of each building in relation to the degradation mechanisms and loss of performance.

Therefore there is a need to develop a user friendly but accurate tool. The ease can be achieved by limiting the number of degradation phenomena observed to the most significant ones for maintenance purposes. The accuracy can be accomplished linking the assessments of maintenance works to objectively verifiable phenomena in survey activities and management (e.g. cracks, etc.).

Furthermore, the method is based on the assumption that many of the degradation dynamics are correlated with the wearing and then with the age of the building elements. The instrument used for the purpose of collection of the information on the in-service behavior of the building parts is represented by the FMEA methodologies. Such analysis allows identification of the causes and consequences of failures on the building component and on the system as a whole. This assessment is reflected on the one hand in the identification of the individual phenomena of degradation. On the other to the classification of the consequences on the system in terms of compliance with safety requirements, energy saving, functionality and appearance and maintenance works needed.

The assumptions of the methodology are:

- The subdivision of building’s components into functional element;
- The identification of the main technological features of the materials used (e.g. concrete-based plaster, wooden window frames etc.);
- The main failures occurring during the building and components service life;
- The consequences on the building functions in terms of seriousness and priority;
- The maintenance works consequent to the failures;
- The strategy of maintenance works proposed has been estimated according to practice;
- The amount of C&D wastes produced by the each work considered.

Starting from these assumptions, the degradation levels, maintenance works and C&D wastes can be forecasted. The model has been completely designed and an application has been developed using ArcGIS and Windows Access software.

3. Case Study

The goal of the case study is to evaluate the amount of C&D wastes that can be produced yearly by maintenance and refurbishment of residential building stock in a city district by the forecasting model described.

The research has been focused on the district Le Vallette in Turin, a residential area of about 680,000 square metres (Fig. 1). This neighborhood was built after the Second World War as a public housing development to address the increase of housing need due to growth of the city. The buildings were built by several housing agencies and managed for decades by ATC. Nowadays building stock has been sold partially to the tenants. In this district the buildings were built following the same standards and technologies above all for envelope, structures and internal finishing. Moreover the building stock analyzed has been partially refurbished and maintained by ATC technical staff. The neighborhood is composed by 253 apartments buildings that can accommodate more than 8,000 people.

The forecasting of maintenance works has been focused on the main interventions relating to the building envelope (façades and roofing), the refurbishment of apartments (fittings, interior finishes, screed, floorings, internal partitions, etc.) and the replacement of external pavements (parking lots and roads).

Table 1 shows the most significant features of the residential buildings and external area of the neighborhood in regard to elements considered in calculation. The rate of renovation of the apartments has been assumed by real data of ATC management systems, based on a sample of more than 31,000 apartments in Turin. Every year ATC refurbishes about 800 apartments. Such works are scheduled when the tenants of the apartments move. This amount of works is easily assessed considering the rules of the agency in regard to standards to be complied by law.

The evaluation of the repairs and replacement of the external masonry wall has been carried out taking into account only the more deteriorated façades. Nevertheless the failures detected in such elements do not require necessarily urgent interventions for safety reason (Priority 1). Such failure (the surface spalling of external brick wall) actually could actually have serious consequences on functionality of the wall and requiring a complete rebuilding of the wall. Therefore in the calculations we have assumed the need of replacement of the wall but only for the more widespread phenomena.

For the evaluation of roof maintenance we assume

Fig. 1 GIS model of Le Vallette, Turin.

Table 1 Case study—district Le Vallette, Turin. Residential building envelope data.

Envelope elements	Technology	Quantity [m^2]	%	Data source
Roof		144,867		GIS of Turin, average slope 27°
Opaque envelope (external surface)	Total	326,381		GIS of Turin
	Plaster	58,749	18%	Estimated from survey
	Brick wall	267,633	82%	Estimated from survey
Glazed envelope	Total	44,507		GIS of Turin
	Wood frame + single glass	8,901	20%	Estimated from survey
	PVC frame + single glass	15,577	35%	Estimated from survey
	Aluminum/steel + single	8,901	20%	Estimated from survey
	PVC frame + double glass	6,676	15%	Estimated from survey
	Aluminum/steel + d.g.	4,451	10%	Estimated from survey
Apartments: Total apartments/total apartments renovated per year			3,897/97	
Road and parking lot area: Total area asphalted [m^2]			283,970	

that the façade repair can be combined with the roof repairs in order to save money by using the same scaffolding. The roof tiles replacement is often required in these buildings that are more than 50 years old not refurbished yet.

4. Results

The outcomes of the estimate have been calculated on the basis of survey carried out by research team from May to July 2018 following the methodology described. The evaluation of C&D wastes by the refurbishment of apartments takes into account standard works by ATC agencies when the tenants move from the apartments. The amount of wastes (Table 2) due to maintenance and refurbishment in the case study of Le Vallette is approximately 3,000 tons per year, about 0.4 tons per person per year. In the last decade the pro capita production of C&D wastes in Italy is about 0.8 ton/year.

About half of the C&D wastes are from the refurbishment of apartments.

For only building envelope, the average quantity of C&D wastes produced in the sample of buildings investigated has been estimated in 0.13 tons per person per year, about 1,100 tons total per year.

A raw comparison with the literature about the amount of C&D wastes at the national level as well as the amount of refurbishment and maintenance on the construction sector output seems to comply the results from the case study analysis.

As a conclusion of this phase of the research we can assume that the model and software developed show a significant amount of C&D wastes coming from refurbishment and maintenance works. Furthermore the georeferenced data allow us to identify the most critical buildings. The tool developed can also be useful to address technical survey to assess the reason of the degradation and failures more deeply. The outcomes of the survey based on the development of the forecasting model of building maintenance and refurbishment applied to a relatively small sample suggest a good fit of the model with the real behavior and durability of building elements. Nevertheless we have to remember that the amount for the quantity of C&D wastes could change following different maintenance strategy and standards. If we considered only the more critical failures requiring quick interventions and the apartments refurbishment, mainly related to the housing market trend, the amount of C&D wastes can be reduced from 0.4 to 0.2 tons per person per year. The amount of C&D wastes produced by the maintenance and refurbishment of building in a residential district is considerable. Also taking into account the most urgent interventions and the business as usual turnover of tenants the estimate is about 30% of total amount of C&D wastes in Italy. If we consider all works forecasted by the model, the percentage rises to about 50%.

Table 2 Case study—district Le Vallette, Turin. Amount of C&D wastes result.

Envelope maintenance works	Materials	Surface [m^2]	Volume [m^3]	Weight [tons]
Roof	Roof tiles	8,090	1,396	299
Opaque envelope (external surface)	Plaster	25,832	387	697
	Brick wall	1,353	162	93
Glazed envelope	Wood	45	2	2
	PVC	111	2	2,5
	Aluminum	67	1	2
	Glass	2,513	10	24
Apartments refurbishment	Materials	Surface [m^2]	Volume [m^3]	Weight [tons]
C&D wastes	Bricks	1,516	182	219
	Aggregate	25,125	503	906
	Metals	375	8	52
	Wood	1,525	61	73
	Ceramic tiles	6,850	137	205
Road and parking slot replace		Surface [m^2]	Volume [m^3]	Weight [tons]
Replace area per year (0.03 m thickness asphalt replace)		8,519	256	690
Total amount of C&D wastes		Surface [m^2]	Volume [m^3]	Weight [tons]
Plaster		25,832	387	697
Bricks		2,869	344	312
Metals		442	9	54
Glass		2,513	10	24
Wood		1,570	63	75
Aggregate		25,152	503	906
Roof tiles		8,090	1,396	299
Ceramic		6,850	137	205
Asphalt		8,519	256	690
Total			3,105	3,263

5. Conclusions

The large amount of C&D wastes shown by the research implies a more accurate separation of materials. For maintenance and refurbishment activities the relatively high cost of collection of C&D wastes, although very significant in quantity, requires innovative policies to improve reuse and recycling materials and building components.

The considerable amount of waste produced each year leads to the idea of setting up collection centers located in urban areas capable of treating waste materials before they reach landfill sites. The adoption of such a policy would improve the quality of collection allowing a better separation and recycling of materials. Nevertheless a revision of the policy could require innovation also in legislation.

On the basis of the results of the research we observe:

- The calculation method developed allows a quick assessment of maintenance workloads as well as C&D wastes;
- The use of the GIS and of existing database can help to assess the amount and geo localization of C&D wastes improving the management of recycled materials;
- Durability and technical features of materials and components affect the urban waste cycle and the urban regeneration and can be improved highlighting the importance of quality of materials.

The research and case study appear to have been answered and to be relevant also for investigation in other urban context and the methodology could be improved with the contribution of specific tools as BIM.

Acknowledgments

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Ju Er Hutong Project: A Rehabilitation Model or an Unsuccessful Attempt?

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Abstract: What will be the future of Chinese urban heritage in the context of globalisation and a socialist market? Ju Er Hutong, as one of the first rehabilitation projects to take place during China's late-1980s housing reforms, is generally considered a successful initiative in terms of urban regeneration and historic area conservation. To what extent does this success demonstrate a capacity to develop new policies and a new planning approach in the current Chinese urban regeneration process? To answer this question, and to summarize its achievements and its remaining unsolved problems, this paper provides the following insights: (1) an analysis of the evolution of Ju Er Hutong to its current form; (2) a literature review concerning the background and the outcome of the rehabilitation process; and (3) a critical assessment of the overall process, so as to summarize its constitutive advantages and problems.

Key words: Urban heritage, old city preservation, Ju Er Hutong, urban restructuring, conservation.

1. Introduction

Widely documented Hutong is an important carrier of the urban culture of Beijing, and is the basic unit of spatial structure within the ancient city, through which the principles of its organization take shape. In order to offer a description of the Ju Er Hutong (Chrysanthemum Lane) preservation policies and to provide a critical assessment of their implementation, it is worth examining its historical and morphological evolution.

In order to better understand the original formation of Ju Er Hutong and its correspondence to the symbolic hierarchy of housing patterns in ancient Beijing, a set of important spatial characters and spatial evolutions will be presented.

The formation of the Chinese urban morphology, with its rigid symmetry and formalized symbolism, was based on the guidelines in Rites of Zhou, a fundamental work on State bureaucracy and organizational theory. Its chapter Kao Gong Ji, a set of assignments and guidelines compiled by realm officials, acted as an official technical regulation. The basic architectural housing typology in China was the courtyard house, whose dimensions were all predefined by urban schemes. The most common housing unit corresponding to an administrative unit within the residential spatial organization of Beijing, generally called Li Fang, was shaped before the 9th century. At the end of Song dynasty (960-1279), there were 62 Li Fang in Beijing. Each Li Fang corresponds to a rectangle of land of about 0.2 km^2 [1]. The word "Fang" means "square", which indicates the original geometric units. Walls enclose every Li Fang and the gates were closed and guarded every night. Outside the walls, the main roads are symmetrically aligned, while residential buildings were built along the small internal alleys and form the sub-zones [2]. With the development of commercial activities, the frontier between the commercial and residential areas was removed, but the function of Li Fang was redefined in an administrative unity, now called "Fang Xiang" (meaning "block and lane"), abbreviated as Fang and maintaining the same surface area. Ju Er Hutong

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belonged to the Fang called Zhao Hui. In every Fang, there were also small markets and schools that constituted a new settlement system, serving basic economic and social functions.

Beijing became significant when it was rebuilt in 1260 by Kublai Khan as the capital city of the Yuan dynasty. The reconstruction was based on the guidelines of Kao Gong Ji and followed the spatial structure of the previous capital cities [3]. The scale of every category of streets and the technical width between two Hutong (44 steps, about 67.76 meters) was predefined in the Kao Gong Ji (Fig. 1). According to Deng [2], the surface of the basic unit of the block is about 4,535 m^2, meaning that one Hutong could include ten normal courtyard units. This conforms to the "square form" of the spatial model mentioned before. By this regulation and the consequent urban texture, the urban morphology of ancient Beijing was perfectly shaped. At the same time, it gave birth to the urban form of Ju Er Hutong which has played a core role in the historical area of Beijing until today.

During the Qing dynasty (1644-1912), the policy of separation of military and residential functions influenced the formation of Ju Er Hutong. In general, Manchu and Mongolian military communities, as the most efficient military organizations and having high social and political positions, were all settled in the Internal City (Nei Cheng), while the ethnic Han community could only live in the External City. The area of Ju Er Hutong was located in the northeast part of the Internal City and administrated by the Manchu [4]. Therefore, its population of roughly 2,500 people was comprised entirely of Manchu soldiers and their families. At the end of the Qing dynasty, the Han community were allowed to live in the Internal City and the restriction of settlement to Manchu and Mongolian military communities was lifted [5]. After this, the social composition of local residents and its impact on the spatial organization of the urban fabric became more complicated.

Despite these changes, the urban fabric of today's Ju Er Hutong evolved according to the traditional housing typology of Chinese architecture. Its pattern was based on different sizes of courtyard buildings articulated organically, in order to form an articulated building system [3].

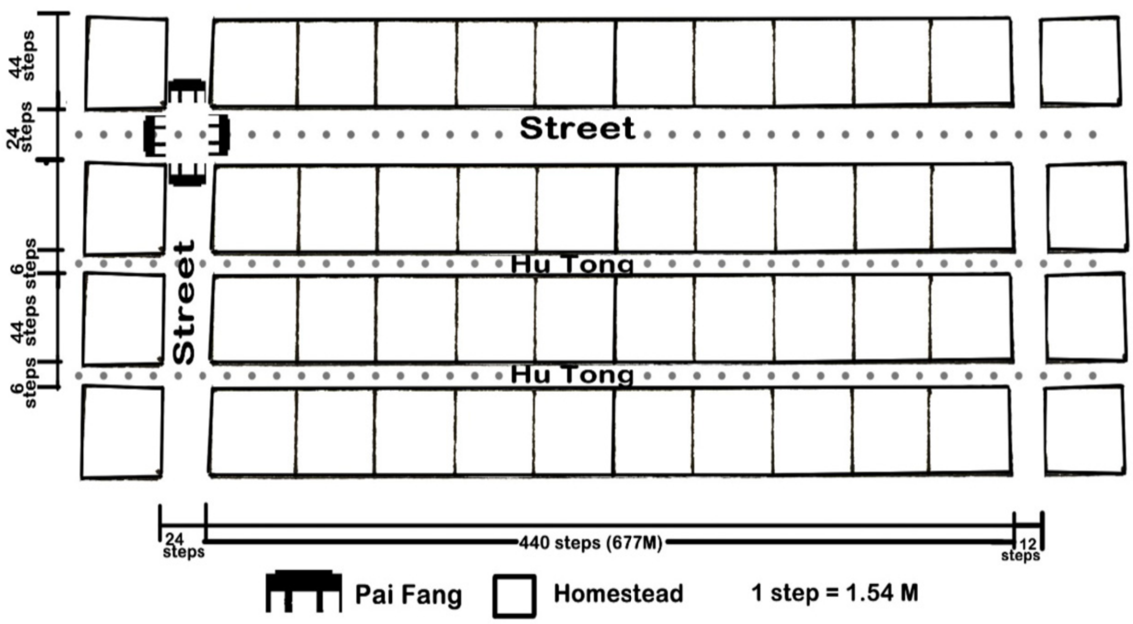

Fig. 1 The basic pattern of the urban block composition of Beijing during the Yuan dynasty, based on the Hutong system.
Source: Deng [2].

2. Methodology

This paper is based on a series of literature review on the Chinese urban morphology and the existing research outcomes related to the morphological transformation of the case study. In order to provide a critical assessment on the overall approach of the rehabilitation project, we carried out field survey in March, 2016 and 2017 to better understand the modifications and social transformations occurred before/after the accomplishment of the project, some recurrent issues concerning physical/societal spheres in today's Ju Er Hu Tong has been emphasized and argued. Particular attention has been paid to the interventions of the built environment.

Last but not the least, we conducted observation in the field, concerning: (1) spatial transformations of indoor and open spaces in Ju Er Hutong; (2) social composition and daily activities of inhabitants; (3) spatial relation between Ju Er Hutong and the surrounding area, paying particular attention to the influence of planning background and subsequent impact on the tourism development and the changes occurred to local inhabitants.

3. A New Type of Courtyard House as a Model for Old City Rehabilitation

The Ju Er Hutong rehabilitation project was one of a number of experimental projects aiming to establish new urban renewal solutions in housing settlements with high historical and environmental value, including a specific conservation plan focused on the South Gong and Drum Lane area.

Ju Er Hutong rehabilitation project (8.2 ha) was designed by Wu Liangyong, a Chinese urban planner and a professor in urban planning, architecture and design. The project is currently cited as an award-winning case due to its attempts to adopt more conservative (or at least less destructive) measures for the maintenance of the historical fabric [6]. The project used the principle of "organic renewal" which was designed "to keep the part still in good shape, repair some of the walls and roofs, and make new construction only when we have to". However, the realization of his idea appears controversial and another interpretation given by Ian [7] is more likely to be appropriate to the situation: "instead of clearing out entire neighborhoods, you saved what could be saved and built similar-sized and similar-looking buildings to replace those that truly were hopeless".

To untangle this controversial matter, it is worth summarising the process of the whole project to establish close insights into its achievements and failures. The project was developed in four distinct phases (Fig. 2).

The first phase was focused on No. 41 Courtyard, a small area of 0.209 ha where the dwellers lived in extremely poor conditions and the residents had a strong desire to improve their living standards. Frequent flooding, lack of sunlight and distant public toilets all contributed to a poor quality of life. Moreover, in order to create additional space for expanding families, the public space in the courtyard was illegally occupied, resulting in 84% of the plot being covered by buildings, as opposed to the planned proportion of 58%. After a series of studies on the spatial characteristics of traditional courtyards, the design team decided to utilize the so called "standard courtyard buildings", reorganizing the spatial structure by adding two levels to both the south and north sides and one level to the west and east sides to increase the per capita living space. Furthermore, considering the needs of residents, the design team conceived several types of layout equipped with kitchen and bathroom, and also some outdoor spaces such as balconies and roof terraces. During this phase seven old courtyard houses were demolished, and 46 apartments were newly constructed, which resolved the basic living problems for 44 families (the other two apartments were sold at the market price).

The preparation for the second phase, including an

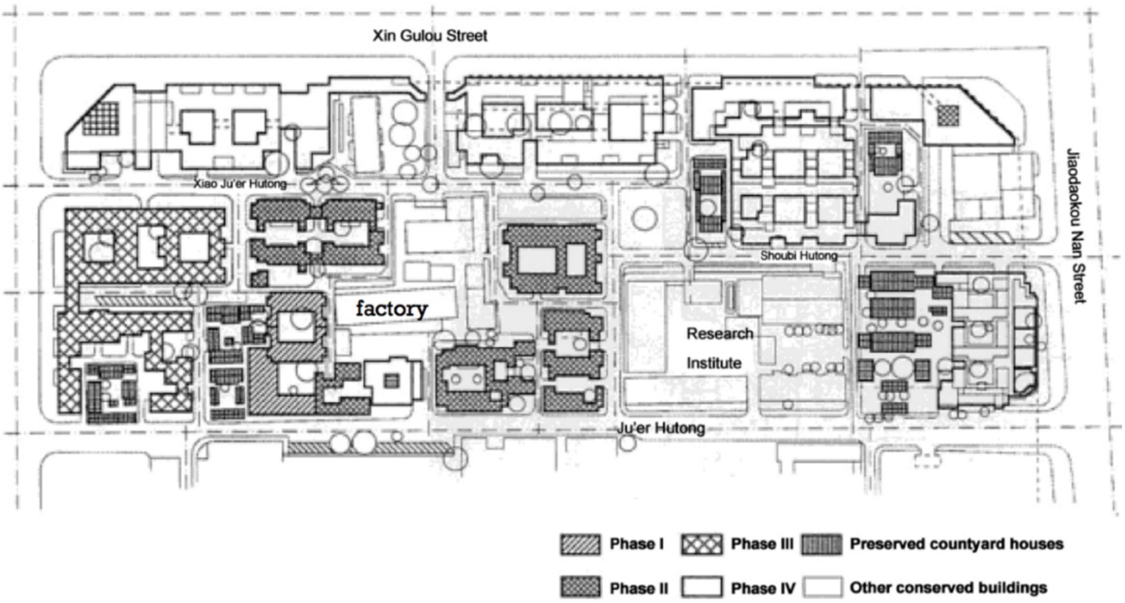

Fig. 2 Master plan for the Ju Er Hutong rehabilitation project.
Source: Wu [8].

area of 1.14 ha, started immediately after the completion of the drawing preparation of the first phase. The main area of the second phase actually encircled a factory, which was obviously difficult to relocate because of its spatial character. For this reason, only one storey of the factory was included as part of the second phase of the rehabilitation project. In this second phase, instead of the rectangular form of the new courtyard building of the No. 41 Courtyard, a more various form of courtyard plan was applied in order to meet the requirements of 192 dwellers as well as to save the ancient trees and to leave space for the circulation system. In addition, the issue of community's social construction was taken into account, consequently a community center of 300 m^2 was also completed.

The third phase involved an area of 0.88 ha, composed of various other building types. First, for the residential section, seventy-one apartments were built, creating 6,116 m^2 of residential floor area of 86.1 m^2 per household. The courtyard buildings were designed with greater open space and more "narrow form" units. Secondly, the project started to focus on developing mixed commercial-residential buildings alongside public service spaces. For instance, the floor area of a hotel of 1,704.3 m^2 was doubled [8].

The final phase included an area of 6.58 ha and adopted the same design approach. It should be stressed that in this phase most of the residential areas were transformed into commercial ones. For instance, a residential nucleus of 19,300 m^2 was converted to commercial space, and consequently 1,200 residents were obliged to move out. Furthermore, 930 families were living in this area, a number which decreased to 500 after the project. Most importantly, in order to create a "multifunctional courtyard compound system", commercial real estate was included in the north of the area, directly facing the main street of South Gong and Drum Lane, with the aim of increasing the income of the whole project [3].

Although the rehabilitation project aimed to preserve the morphology of the traditional pattern and style of South Gong and Drum Lane area, it also included changes and demolitions according to assessments of building quality status carried out by the design team. The buildings present in the area were divided into three categories:

(1) High quality and recently constructed buildings

(such as the two factories erected in the 1970s), constituted 16.2% of the whole area;

(2) Courtyard buildings in fair condition, needing to be renewed and reused, accounted for 6.5%;

(3) Buildings in poor condition, to be demolished, comprised 77.3% of the whole area of 8.2 ha.

In summary, the main changes from the original courtyard buildings to the new ones are as below:

- From a set of volumes with only the ground level to vertical multi-storey buildings;
- From a traditional morphology to a new and more regular one;
- From residential use to a more commercial-touristic use;
- From a low-income community to a gentrified community;
- From a low housing value area to a high housing value area. The low-income inhabitants were mainly displaced elsewhere, changing the social composition of the residents and resulting in a decrease of identity.

3.1 No. 41 Courtyard, a Pioneer Experiment in the Old Urban Fabric Renewal

The new building fabric was based on a new standard courtyard type which was developed on a scale of about 1,000 m^2 including a yard of about 195 m^2. For the sake of improving indoor daylight and to strengthen the live ability of the courtyard, the east and west wings of the buildings were reduced to two levels. Moreover, through adopting a varying range of architectonical elements, a series of external, private and semi-private spaces were created (e.g. balconies, terraces, corridors, etc.). It is worth stressing that this variety of architectonical elements was obtained by increasing the costs of a higher plot ratio and a higher fee of construction. Nevertheless, the plot ratio was not high enough compared to the expected average density of renewal (Table 1). As a result, after the completion of the project in 1994, the authorities decided not to extend this experiment to other urban areas in Beijing [8].

At the end of the project in No. 41 Courtyard, the per capita living space was expanded from 5.2 m^2 to 12 m^2 and the floor area ratio was increased to 1.32. Furthermore, the minimum width of the alley was enlarged by adding 2 meters to the north side in order to guarantee an appropriate public space for circulation.

3.2 Finance

The total investment in the renovation of No. 41 Courtyard was 2.84 million Yuan (including the resettlement fees, costs of infrastructure, etc.). In order to provide affordable housing units, a housing cooperative was set up. The thirteen original families who wanted to move back to the renewed courtyard paid the cost of the construction, contributing 1.47 million Yuan through cooperative financing. Those original residents who could not pay the price set by public authorities, or were unwilling to move back, had the right to exchange their units with the residents of other areas. At the end of the first phase of the project, leaving aside the houses rebought by original residents, the other ten houses were sold at a market price totalling 1.4 million Yuan, for the purpose of recovering the construction cost. The total recovery of funds was 2.87 million Yuan, which was sufficient to balance the budget [8].

3.3 Inhabitants and Identity Facing a Commercial and Market-led Development

The original buildings in No. 41 Courtyard included a Ming dynasty-era temple named Hongdeshanlin, administrated by a temple nearby called Yuan'en, which was ruined during the Qing dynasty. At the end of the Qing dynasty, the No. 41 Courtyard fell into disrepair. After the invasion by the Japanese army, many people settled in this yard to start their new life in the context of the new socialist society. It's noteworthy that before the foundation of the New China, housing stock had been exclusively in private ownership. However, after the first Five-year plan (1953-1957), the socialist goal of providing a shelter for everyone

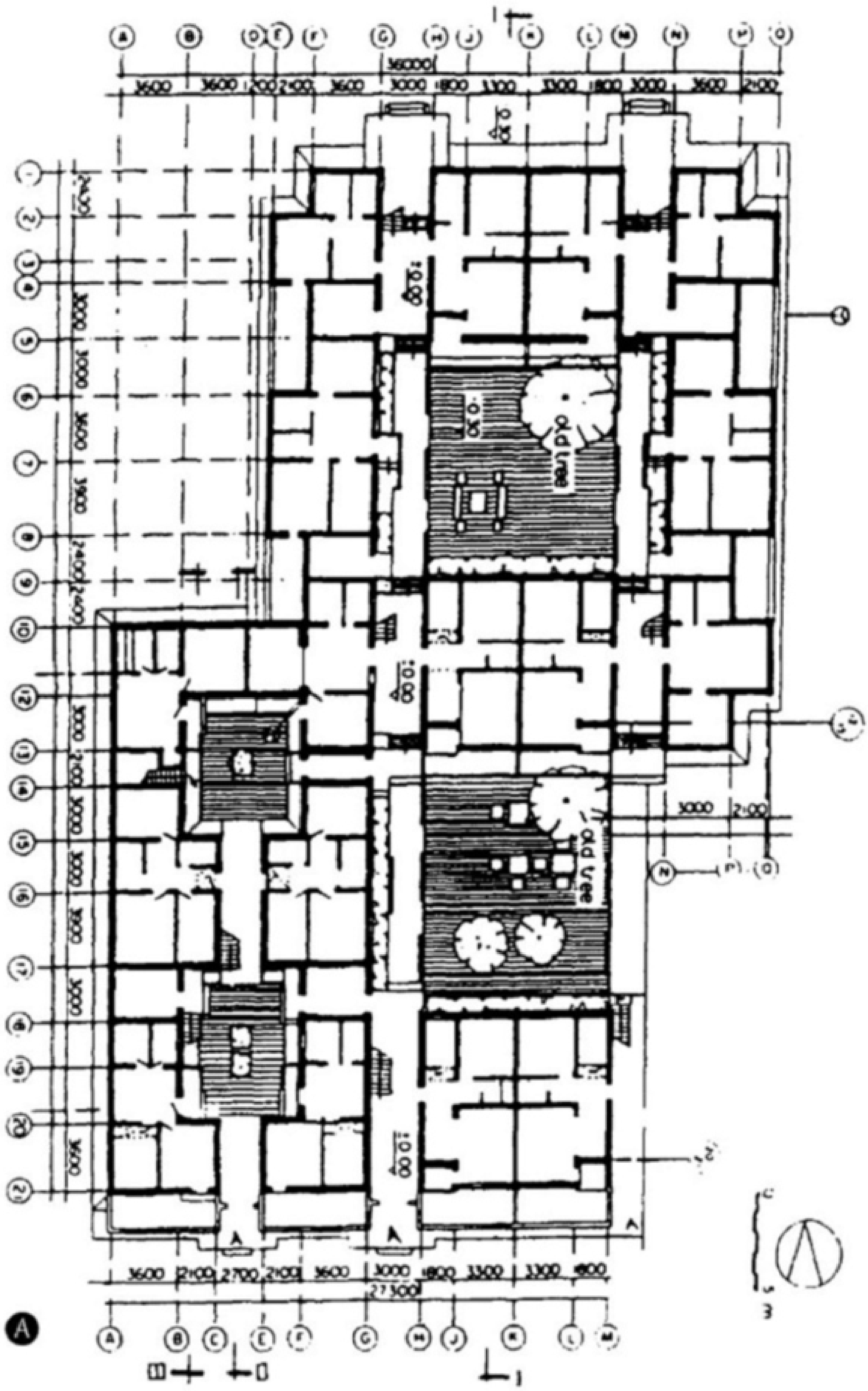

Fig. 3 Plan of the ground floor of No. 41 courtyard.
Source: Wu [3].

Table 1 Statistics for Ju Er Hutong before and after the rehabilitation of No. 41 courtyard.

	Floor area	Dwellers	Dwellers per household	Dwellings	Density (dwellers/ha)	Floor area per person	Illegally built area within the courtyard
Before	1,085	138	3.14	41	673	7.86	450 m^2
After	2760	133	2.98	46	649	20.75	0 m^2

Source: Wu [3].

transformed house ownership profoundly, as private housing was transferred to the ownership of the local authorities. As the result, many working-class families coming from rural areas moved into courtyard houses [9], so that "multifamily courtyards" gradually formed, which were called "Da Za Yuan", (meaning "big messy yard"). Inevitably, in order to increase living space, residents transformed various rooms of the Hongdeshanlin Temple into residential ones. In the 1980s, there were 24 families (85 people in total) living in No. 41 Courtyard simultaneously [8]. Alongside the issue of the increase in inhabitants discussed above, at the end of the 80s, the majority of residents in No. 41 Courtyard were young people. Although the population was limited by the one child policy, a further increase in residents could be expected reasonably. In fact, as we can see today, the current spatial structure is not able to meet the increasing demand of dwellers.

The rehabilitation project altered the composition of residents at the beginning of the 90s. The thirty-one families who decided to not purchase a dwelling in the new courtyard, or could not buy the units where they lived before, were given three choices as follows:

(1) To resettle to other government-owned housing located in the old city, generally in bad condition;

(2) To move to new residences located outside of the old city and provided by the government at a low price as one of the benefit conditions;

(3) To exchange their purchase right at the preferential rate for a house elsewhere [8].

According to the survey on the status of resettlement of original and new inhabitants, thirteen original families returned to the new courtyard together with thirty-one new families, and half of them reported feeling at home after having lived in the new type of courtyard for one year [10]. Meanwhile, four families were relocated to new residences situated in suburban areas, twenty-one families moved to other residences inside the old city, and six families used their "right of exchange" and purchased a house elsewhere.

Most residents apparently did not want to leave the old city because it offered more convenient transportation and educational conditions. However, by simply providing higher-quality housing at a lower price, the public authority and the design team received positive feedback from those families who moved out. In 1990, 26 of 31 families participated in the post-project survey of No. 41 Courtyard, and as Wu [8] states: "none of those surveyed expressed the regret over the choice they had made".

Today, householders who are still living in poor quality courtyard buildings expect renewal of their homes as in the 1989 project. The current housing price in the renewed area is above 100,000 Yuan (about 13,600 euro/m^2)[1] and is still growing, so Ju Er Hutong can be counted as part of the Beijing "urban renaissance" process, as well as under threat of gentrification [11].

4. The Transformation of Public and Private Spaces

In ancient China, public spaces were usually huge in scale for gatherings of political servants, and their use for free association was prohibited in order to prevent popular revolt [12]. Open spaces for public civic activities were rare because the city was clearly divided into residential and commercial functions. But today, public spaces are a fundamental aspect of cities' live ability, as they encourage everyday activities, and increase social interaction [13]. Therefore, it is worth recalling the specificities of the public spaces in ancient Hutong:

- Thousands of years of feudal society had fettered the formation of an autonomous public space, so their locations were mainly related to indispensable daily activities based in a linear common space, called a Hutong, a lane acting as an extension of residents' living space.
- The small scale of their open space made them

[1] Data from website: http://esf.fang.com/house-xm1010215845/. Accessed 20, January, 2018.

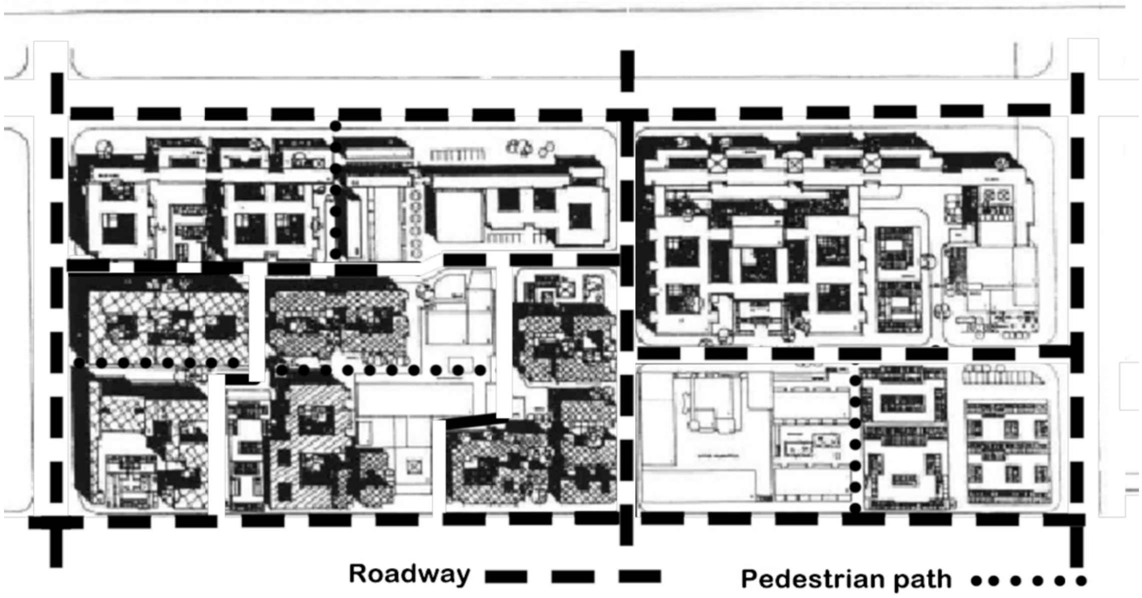

Fig. 4 Approach system of Ju Er Hutong.
Source: Sun [10].

easily reachable and perceivable. Therefore, they were also suitable for pedestrian mobility and small business activities.

Thanks to the rehabilitation project and many other conservative schemes[2], the residential function of Ju Er Hutong maintains its relevance, but we do see that the whole area has transitioned to a double functional value: residential and commercial-tourism. Therefore, it can be considered an intermediate solution between traditional residential area and commercial area.

4.1 Public Paths among Courtyard Compounds

In view of the belief that "Hutong are the blood capillaries of Beijing Old City", the rehabilitation project attempted to maintain this urban character. The design group took the networks of the courtyard compounds in Suzhou as a reference, inserting long paths of about 50 m among the courtyards, so as to draw influence from traditional urban morphology and recall the ancient Chinese space of daily interaction (Fig. 4). Yet today, due to the socioeconomic development of the area and the increased demand for leisure and sportive activities, the paths and other open spaces have not achieved an appropriate scale; as a result, the current public spaces do not match the modern lifestyle of the residents. As we can notice, the outdoor activities of residents in Ju Er Hutong take place directly in the alley, which is mainly used for circulation of cars. Besides this, the only green spaces are a few trees conserved in courtyards.

4.2 Public Services

Public services, including social infrastructures such as education, medical care, sports, etc., are an important indicator of the quality of life of residents [14]. In Ju Er Hutong, the only focal point for the gathering of people is the Community Center, a new traditional-style building constructed during the second

[2] In 1999, Beijing municipal government issued the *Planning on the Protection and Control Scope of the History and Culture Protection Area of the Old City of Beijing (April 1999)* as a general initiative action in order to establish more detailed plans. Furthermore, the Beijing Municipal City Planning Commission worked with many universities and institutes to produce the *Conservation Plan for the 25 Historic Areas in Beijing Old City (Beijing Municipal City Planning Commission, 2002)*. The South Gong and Drum Lane area and Ju Er Hutong were included. The *Conservation Plan* evidenced the goal "to preserve the overall style and features of the historical areas" and "to improve environmental quality and infrastructure as well as residents' living standard…".

phase of the project which includes an administrative office for the community, a youth activity center, a senior activity center and a community health center. In the Center, a variety of youth activities (e.g., lecture courses, photo exhibitions, and education on law) have been held from the early 90s until today. Besides the public services mentioned above, Ju Er Hutong has few appropriate spaces for sitting and walking due to its "street" spatial character.

It should be also added that congested and chaotic parking is another issue in today's Ju Er Hutong. In Ju Er Hutong, the urban road area ratio is about 15.7% which has effectively reduced the traffic on the main road [10]. But on the other hand, it produces hazardous circumstances. Although the multi-scale approach system of Ju Er Hutong offers a convenient mode of mobility, the parking issue needs to be resolved for the purpose of improving the safety and urban landscape of the area. In fact, some laws and regulations have introduced possible measures and solutions to resolve the traffic problem. For instance, *Measures for the Protection of the Historical and Cultural Landmark of Beijing (Effective)* declared "by utilizing various measures or instruments, to activate practical actions to manage, control and limit the excessive use of private cars in the Old City". However, it seems that Ju Er Hutong and the entire South Gong and Drum Lane area are not implementing these regulations.

4.3 Transformation of Private Residential Spaces from Past to Present

With the earth-shaking transformation of Chinese society over the last hundred years, Ju Er Hutong has witnessed great changes as well. If we consider the transformations occurred in the context of strictly residential spaces, a variety of significant findings emerge.

The culture of Chinese architecture is fundamentally a culture of courtyard buildings. Whether in palaces or in ordinary houses, courtyards have always been a matrix unit of urban form [15]. The yard also represents the ancient Chinese attitude to the environment, which is reflected by Chinese Feng Shui philosophy. The yard was used for outdoor activities and as shelter from the wind. Besides all these practical functions, the enclosed space offered residents a sense of belonging, improving social cohesion. Enclosed space not only helps to gather individuals and families into a social unit but also permitted the Chinese people to maintain the traditional family model in a relatively stable state.

The yard is also a way to "integrate nature and humanity", which is the core of Taoism. The scale and the volume of building and yard and their close correlation with natural conditions, psychology, and architecture can even reveal surprising results through scientific methods [16, 17]. In Taoism, it is emphasized that "harmony with circumstances" is one of the main criteria when choosing a favorable site for construction, so as to respect nature. The "cosmic breath", wind or energy could be interpreted as "microwave radiation from the sun" [9] that nourishes all things and gathers positive energy for the family. The spatial configuration of the courtyard buildings is considered effective in gathering such energy and refining the circulation of the microclimate. Moreover, the well-organized spatial structure and the garden in the center of the yard provide physical and psychological comfort for inhabitants.

The Ju Er Hutong rehabilitation project started with an intention to keep the matrix of the old courtyard and each compound is organized as two or three single-courtyard buildings, each containing a yard of about 100 m^2. Balconies and terraces were designed to create passages and spaces for communication. Besides the improvements in living conditions mentioned above, the volume, the scale, and the facades of the new courtyards have been totally changed. The new type of courtyard was designed to recapture the emotional experiences and intuitive feelings that the spatial character of the traditional courtyard had brought to people once, in order to enhance the affinity of the neighbourhood.

Table 2 Four examples of recovery between preservation and rehabilitation.

No.	Name of buildings	Location	Typology of intervention
1	Rong Lu Western style building	Ju Er Hutong No. 7	Partial renew of historic elements
2	Gu Fang Hotel	Ju Er Hutong No. 33	New building shaped with images of ancient architecture
3	Residential courtyard building	Ju Er Hutong No. 103	Original historic remains reshaped by inhabitants
4	New type residential building	Ju Er Hutong No. 41	A rehabilitation dialoguing with historic remains

Source: Elaborated by authors.

Today, about 40% of residents are elderly people and children, whose main activities are household chores, gymnastics and conversation. The yard functions as a semi-private space shared by different families, where daily interactions take place. Nevertheless, based on the survey on feelings of belonging, in Ju Er Hutong, only 20% of residents think that the new type of courtyard provides the same ambience as the traditional one [10]. Moreover, due to mismanagement by the community, most balconies and terraces are being used as deposit areas, and the corridors are full of rejected materials, which increase the risk of fire.

5. Four Typologies of Recovery, between Preservation and Rehabilitation Project

Closely examining the solutions offered by the rehabilitation project in Ju Er Hutong, it is possible to identify various different modes of interventions based on different conservative approaches (see Table 2).

The first mode is the partial renewal of residual elements. Some of the real historic remains can be only traced by identifying the existing architectonical elements and the steles in front of the buildings. The Rong Lu[3] Western style building is one example of this. Rong Lu mansion covered half of the alley, being divided into three sections from west to east, with a western-style building in the west. Unfortunately, although in 2009 it was listed by the district level cultural relics protection unit, only the basic structure, the façade and the external Western style architectural elements have been conserved; the interior has been reconstructed and transformed into a luxury restaurant. In fact, it is a struggle to identify and apply the correct modes of preservation, as the eruption of tourism and rapid economic development strongly influence the practices of conservation of historic centers in China [18].

The second mode consists of the "reinvention" of ancient architecture. One example is located in the Gu Fang hotel, No. 33 Courtyard. This building represents the majority of recently built pseudo-traditional style buildings whose primary function is commercial. It is artificial although it serves the purpose of attuning the building with the surrounding urban landscape.

[3] Rong Lu, (6 April 1836-11 April 1903), was a Manchu statesman and general in the late Qing dynasty.

The third mode refers to buildings completely or partially reshaped by inhabitants for their basic living purposes (e.g., No. 18 Courtyard). This type of intervention is mainly based on maintenance works, and distributed on the south side the lane, where an appropriate conservative measure still needs to be applied to the courtyards (or the still existing "multifamily" courtyards near to No. 18 Courtyard, where it is hard to trace constructive information for individual rooms). Most inhabitants are living here for a short period while in transit during resettlement from other historical areas undergoing renewal projects, and so demonstrated little interest in being visited and interviewed.

The fourth group includes the Ju Er Hutong new courtyards. It is an experimental prototype that, thanks to its redesign and reorganization of traditional courtyard buildings, was considered a new page in the book of Chinese urban heritage rehabilitation by many scholars and commentators. The urban restructuring aimed to preserve some elements of traditional architecture, not by restoring their physical assets but by recalling their social and functional aspects.

Besides the various interventions implemented by different stakeholders for different purposes, there are other buildings of high historical value that are facing embarrassing situations. The two-row courtyard of Rong Lu Ancestral Hall (in Ju Er Hutong No. 3) is one of them. A few old houses were conserved as a part of Rong Lu Ancestral Hall, which was listed by Dongcheng District Cultural Relics Protection Unit in 1986. Thanks to this nomination, the Rong Lu Ancestral Hall was excluded from the demolition at the end of the 80s. The building, despite its high historical-cultural value, is suffering from ineluctable dilapidation today. And yet, Rong Lu Ancestral Hall is not a lone case of unsuccessful implementation of conservation regulations. No. 107 Courtyard is a site protected at the district level, and was presumably property of a Qing-dynasty court official (the stone piers indicate the political position of the household). Despite this, although the integrity of its main door, its building ornaments, and the roofs still demonstrate high historical and artistic value, the courtyard isgravely degraded. In view of the difficulty of finding its original owner, it remains unclear where responsibility for its preservation should lie.

5.1 A Spontaneous Commercialization Process

Ju Er Hutong rehabilitation project produced both an improved residential fabric and a set of related activities. As a consequence, today in the area more than twenty new commercial activities have developed, which are profoundly changing the character of the area. The symbolic design strategies were born to meet the growing nationalism of a powerful country, meantime, "satisfying the emerging commercial elites in a society of growing capitalism" [19]. This Hutong weaves together a number of street frontages, providing the potential for development of commercial spaces. During this process of transformation, the mixed functions make the urban spaces more attractive and liveable. Original residents, foreigners, artists and shops share the space of the Hutong, creating a new cultural environment. On the other hand, an excessive presence of non-residential use leads to a state of social imbalance. As a result of the emergence of commercial spaces, restaurants and bars and other public facilities, the façades as well as the interiors of the houses are filled with modern and foreign elements (e.g., No. 20 Courtyard). In No. 41 Courtyard, the ground floor facing the alley was entirely rebuilt to house a restaurant and a cafè.

In summary, this rehabilitation intervention has involved the reconstruction of a residential system. It has produced an economic revival in the neighborhood which resulted in the launch of a set of tertiary businesses. These activities have been established along the street frontages by replacing previously residential buildings with new buildings.

The public space of the Hutong, previously a lane closed by walls on two sides and occupied by outdoor trade activities, has become a “street” with open commercial frontages, often expanded into the inner courtyard. This transformation has produced a total alteration of public space as well as an explosion of retail space, and has also modified the formal articulation of residential spaces.

5.2 Spontaneous Interventions, and Small-scale Renewal according to the Demands of Residents

In the courtyard building area of Old City in Beijing, self-maintenance interventions are the most widespread. Interventions implemented by residents are always carried out on a small scale. According to the data provided by Beijing Cultural Heritage Protection Center, 69% of Old City courtyards were renewed or restructured through spontaneous interventions from 1998 to 2008. It appears that the self-maintenance mode is a good practice because it partially reduces the financial pressure on public authorities, and permits residents to participate more actively in projects. But in many self-maintenance cases, the renewal is hampered by the low economic capacity of the inhabitant. Despite this, compared with large-scale government-led renewal projects, self-maintenance renewal led by residents has the following advantages: (1) the interventions have clear and simple objectives like kitchen-improvement and pavement resurfacing, and it can be accomplished according to personal preference; (2) the self-maintenance process is much more flexible than government-led operations. In an urban renewal project, the government would firstly conduct a survey of the area, then formulate a unified and multi-level protection policy, and finally allocate funds to renovate the area. As such, the needs of each house with different physical conditions and every resident with different demands cannot be fully taken into account under the uniform standards. On the other hand, it should be clear that self-maintenance renewal has its own disadvantages: the lack of professional technical support, and the weak motivation of local residents who are not the owners of their dwellings. State-owned housing is naturally more vulnerable to government policies, and in China’s case, it also reduces incentive to undertake courtyard renewal. In fact, where land and often also buildings are owned by the state or by collective organizations, government decisions prevail over private initiative. In the 80s and 90s, in government-led reconstruction or demolition projects, public housing residents, who were forced to accept the government’s decisions, had no right to express their own ideas and requirements relating to rehabilitation projects. Without a review of the property rights policy, it remains unrealistic to expect householders to invest in ordinary maintenance interventions.

6. Discussion and Conclusion

Having examined the main transformations and impacts produced by the rehabilitation project at the spatial and social level, we can focus on three main issues still requiring more appropriate solutions. These impacts can be examined through three aspects and their consequent socio-economic effects.

6.1 Issues of Design and Maintenance

Several design problems and subsequent maintenance issues have emerged after several years of monitoring:

- Natural light in the west and east wings of No. 41 Courtyard, and kitchen and washroom space, do not adequately meet the requirements of today’s living standards;
- The new type of courtyard is higher than the traditional courtyard, resulting in a depressing psychological influence from current spatial scales;
- The grey and white south China style wall painting has been criticised as not attuned to Beijing Old City’s architectural style;
- The issue of disrepair is evident in today’s Ju Er Hutong, including peeling paint and waste material and garbage polluting the communal space of the yard. Efficient administration needs to be carried out.

6.2 Beneficiaries of the Project

It is a challenge to find any prime beneficiaries/inhabitants who live in the new-type courtyard buildings, and the reason is clear. The inhabitants, discovering that the value of their homes had increased enormously, could hardly have been expected to pass up the opportunity. Therefore, it seems to be quite rational and voluntary for them to decide to settle down elsewhere and to rent or sell their own dwelling at a significant price.

It should be stressed that the high value of the rehabilitated courtyard buildings can be attributed not only to housing marketization and tourism development but also to their desirable living conditions and housing quality, particularly compared with other poor-condition courtyards in the area. In Beijing, the return of the middle classes to the inner city is actually a voluntary action which constitutes part of the reduction of population pressure in the old city; therefore, it does not seem intolerable. But it is contrary to the original intention of the architects who wanted to improve the living environment for local inhabitants. Besides this, the sense of loss for a home constitutes part of the psychological cost of displacement, although it was rarely considered in the rapid process of urban renewal in Beijing. Indeed, under the result-oriented conception, the impacts of gentrification are easily ignored in any scientific approach.

6.3 The Issue of Local Commercial Activities

Furthermore, the development of tourism accelerated the homogenization of diverse forms of industry. Local industry generally existed to satisfy daily needs until 2005. With the increase in tourism and the inflated rents, businesses serving the local community are increasingly being pushed out of the area. Meanwhile, the proportion of restaurant and beverage stores is sustaining rapid growth because of their high revenue [20]. Today, thirteen restaurants and cafés and two creative clothes shops attract a huge amount of tourists and only one convenience store and one laundry serve local residents in Ju Er Hutong. This demonstrates how tourism has influenced and changed both commercial activities and residents' daily lives.

6.4 Conclusion

The rehabilitation of Ju Er Hutong emphasizes the possibility that some of the Old City lifestyle might be preserved through an "organic renewal" method. In view of its outcome, could we consider it an ideal solution for urban preservation in the long term? If we compare it with the large-scale demolition and reconstruction which numerous Chinese old districts have experienced, the answer is yes. But if we consider the long-term in relation to the social and economic context, the consequences might be more harmful than positive.

How to negotiate the conflict between preservation and marketization is still a critical question when formulating policies for the rehabilitation of Chinese historical urban areas. However, in light of its spatial and functional outcomes, the project here presented allows us to recognize some non-secondary aspects concerning its effectiveness. In other words, it gives us lessons and warnings which can be summarized as follows:

(1) With respect to methods of actualizing tradition: the project shows that this type of courtyard house has a high potential for replication in a contemporary context. However, in their current use, the new built courtyards are not used as "community space", and this is only partially a result of the project in itself, stemming rather from a disconnection between the courtyard's living potential and the lifestyles of the new inhabitants.

(2) With respect to innovations in the functions of the central lane: the project demonstrates that it is possible to reintroduce the lanes in more evolved forms, which adapt to new social demands. However, this evolution is likely to leave no room for even a partial conservation of street life, which is today homologated

around commercial activities.

(3) With respect to the maintaining the character of urban forms: while introducing a new type of courtyard house, the project manages to keep some formal cornerstones of the original morphological structure. However, the structure of the new courtyard houses is not fully integrated into the surrounding urban fabric. Besides the two historical courtyard houses preserved, which are rather dilapidated today, 70% of houses were torn down during the rehabilitation project, losing many traces of the original urban form.

(4) With respect to methods of preserving the "telling images" of the historic city: the project conserves one of the few historic elements still present in the area. However, the large-scale replacement of the existing residential tissue led to the disappearance of those elements that could have maintained a dialogue between the past and present city.

(5) With respect to mobility: the spatial character of the Hutong was marked for having mostly parking areas in public spaces. Since there is no prohibition or restriction for vehicles, a mobility system offering a wide range of transportation for local residents and tourists is today active. However, such a system is deficient in terms of health and safety, and a policy to limit mobility is needed.

(6) With respect to social composition: the first two phases of the project managed to keep 25.9%[4] of the original residents due to the creation of a high number of small apartments. This means that 211 new families (about 610 residents) moved into Ju Er Hutong after the rehabilitation project. The precise number of original residents who remained after the completion of the entire rehabilitation project is still unknown. Even considering that a policy to reduce overcrowding implies the replacement of some original residents, their substitution appears to be excessive, and it would have been better to provide greater support to maintain a larger number of them.

(7) With respect to public space: the project produced an increase in housing value which was profitable for diverse types of users, from the dwellers to the traders, but it did not produce a corresponding improvement in terms of public spaces and public services. The preserved old trees in the courtyards constitute an unsatisfactory amount of green space for Ju Er Hutong. These spaces are not sufficient to meet the demands of inhabitants, and in this respect it is hard to expect a revival of a community sentiment which was based on a sense of identity and unique spatial character.

In conclusion, we are not dealing with an optimal solution, but with a serious attempt to reformulate important issues related to the process of transformation of Chinese historical cities. This attempt shows how the limitations of the project above mentioned can be related only in part to the inadequacy of spatial and functional solutions provided by the architectural and planning project. On the contrary, they are due to a great extent to the urban planning regulations and operational conditions (at social, economic and political levels) within which the project was situated. For this reason, concrete progress on the quality and effectiveness of policies for the conservation of historic centers cannot emerge solely from the operational field of architects and urban planners. In fact, many relevant decisions affecting the physical and functional levels, which are expected to remain in the hands of architects and planners, are removed completely from their competence.

Therefore, real progress stripped of rhetoric and misunderstandings can be achieved only if it stems from a profound reconceptualization of the idea of the historical city and its conservation. This must be a reconceptualization able to overcome the current limited operating conditions, which remain bound to market-led preservation goals rather than social and cultural outcomes.

[4] The calculation of the data is based on the statistic table provided Wu 1994, 170.

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“Regulation of Urban Space and Construction in the Late Ottoman and French Mandate Period”—The Case of Beirut (1840-1940)

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Abstract: Starting with the declaration of Tanzimat in 1839, the transformation of administration, law, taxation, property rights, education, urban planning and public works were initiated, which caused the regulation of urban and construction regulations as a tool for achieving a modern state. 1840, the date of the Health of Towns Report, marks a stage in the growing concern with health. The period between 1840-1940 is a recognisable date in history, with the outbreak of the Great War marking the end of an era. It also marks the date of a major enquiry into building laws and it also sees the virtual completion of the process of the incorporation of the health controls into the building regulations. In this date several regulations were enacted concerning the buildings and the streets and implemented in Beirut. The main goal of this article is to understand the impact of Building Codes on the construction of the late Ottoman Heritage and its architectural typology.

Key words: Word, building codes, architectural typology, building construction, conservation historic buildings.

1. Introduction

Understanding an overview of the history can draw the development of characteristics that led to the acknowledgement of built heritage influenced by regulations. Before the 19th century, it is known that several imperial orders concerning the buildings were issued for several reasons, such as regulating the construction types, some building elements (roofs, eaves, terraces, oriels) and building materials in order to mitigate fire risks, and limiting the heights of houses to maintain social order in Istanbul.

Beirut at that time was inside its walls, it was formed by gathered and adjacent houses in a narrow street of 4.5 m width and land with 750 m long and 370 m width, surrounded from its four sides by defence walls. The land use outside the walls was agriculture. It was largely a mixture of mulberry plantation trees and an agricultural land use, which had good influence in the production of silk that began in the 17th century in these garden fields [1]. Few huts were erected within the plantations that were probably built for the cultivation of silk. Huts and small buildings of stone and wood were used as storages, workshops, and small permanent residence houses. In 1839, an Official Record was formulated, promoting the construction of masonry houses and limiting their height to 15 meters only regardless of religious origin. It also requires the regulation of the urban space by the widening of main roads, opening of squares and suggesting new regulation on construction techniques. Growth of Beirut was developed in 19th century when some wealthy Beiruti families escape from the old city to enjoy greenery, a panoramic view and the fresh air. Defensive walls were then demolished, and new construction was permitted to form the Beiruti house with its new architectural typology in 1860s complying

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with new regulations. This paper contributes to the subject by allowing us to comprehend the transformation process as a continuous development of architectural typology and construction in Beirut city adapting some western urban elements and construction materials into Beiruti house.

2. The Impact of Building Codes on Ottoman and French Mandate Periods (1840-1940)

Built heritage presents past developments that are significant to the history of the evolution of built environment. Before 1840, the Ottoman authority issued several imperial orders concerning the buildings, such as limiting the heights of houses according to ethno-religious origin to maintain social order. Although in Europe, similar measures were been taken with different purposes as improving urban health. At that time, Beirut was a small old city with a population of around 8,000 gathered around the port with an urban fabric of 15 hectares organized as networks of narrow streets of 4.5 meters width, that were mainly of two types, the through open ended street which was considered a public right of way and had to be at least wide enough for two packed mules to pass, and the cul de sac, which according to Islamic law, is considered to be the private property of the people having access from it to their front doors. Structural elements were found above the streets called the sabat, a room bridging the street, and the buttressing arches spanning between walls on either side of the street to provide structural strength and support for both opposite walls [2] (Fig. 1). As a result, regulations on buildings and streets, codes on expropriation and land use were adopted and a series of measures were proposed to improve the layout of the Ottoman cities and avoid the spread of fires [3]. The main causes of the fires were candle, lighted coal and inflammation of chimney incomplete hydrocarbon combustion. Thus, the flammable material in construction was then prohibited, the width of streets was regulated according to their role in the road network, and cul-de-sacs were also prohibited [4]. An addition record was formulated promoting the construction of masonry houses and limiting their height to 15 meters only, regardless of religious origin. It also required the regulation of the urban space by the widening of main roads, opening of squares and suggesting new regulation on construction techniques. Again, despite the differences, similar measures were taken in Europe, giving presently the urban scale of many ancient cities. In relation to the buildings, a large arch perpendicular to the street and closed to outside the court, oriented to the north which is the coldest place during the summer, and the central court houses, were main morphologic characteristics. The central court house was identified by the internal courts to protect from noise and dust from the street. Another identified kind was a structure with one level, closed to outside and composed of several rooms arranged in L, or in U shape around a court called fushat ad-dar [5] (Fig. 2). Technical eclecticism comes into view during the second part of the 19th century when the preindustrial city started expanding beyond its medieval walls. The result of the urban expansion was due to the migration of the urban bourgeoisie outside the city walls settling on the rural suburbs [6].

The atmosphere of the quarters attracted wealthy merchants and residents to move out and designed mansions, came to be identified regionally as Beirut's aristocratic class. The new prestigious mansions were designed due to the foreign building materials that became available and technological changes reflect the desire of an emerging merchant class, conducting trade with Europe and emulating western lifestyles. The use of imported materials from different sources: wrought-iron I-beams and roof tiles from France, mechanically-cut timber from Romania, cast-iron balustrades and hardware from England, and marble tiles and slabs from Italy [8], was growing. Such exchange may have inspired the merchant's choices in new house design. The merchant class wanted a more comfortable residence where he was protected from the leakage falling from the flat earth roof if it was not rolled

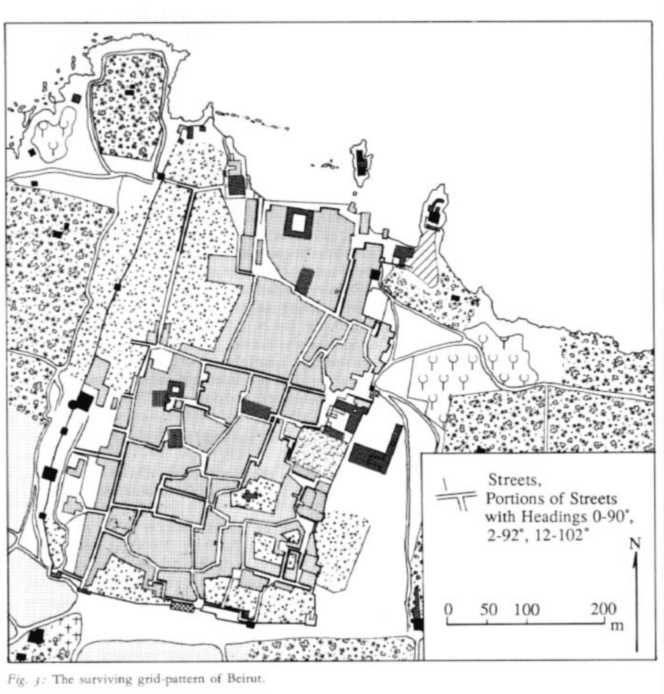

Fig. 1 Old Beirut Map (1840), showing its border, gates, edifices and fortification towers [7].

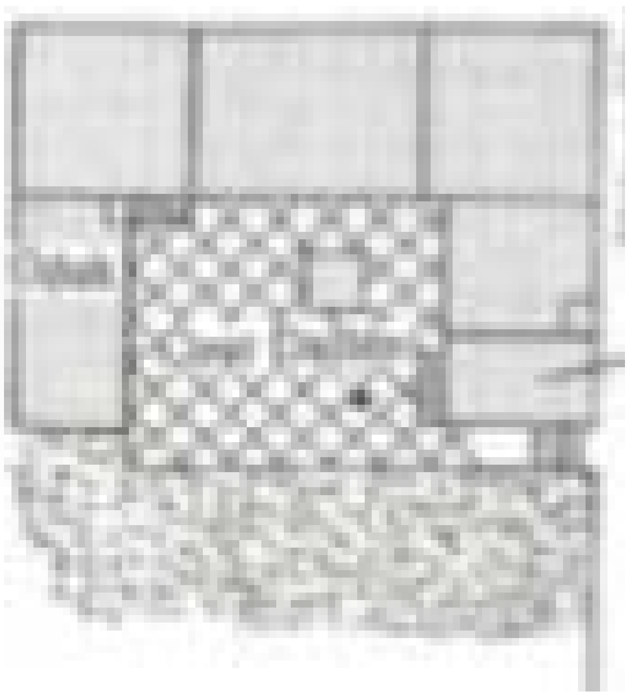

Fig. 2 Plan of Mansour Eddeh in old Beirut, 1850 [7].

during autumn. Merchants travelled to France, and saw the tiles and their advantages giving away the flat earth roof and expressed a desire to copy the Occident. This expansion led to the creation of a new building type, two symmetrical rooms were added to the *iwan* to form the Beiruti house, with its triple arch, central hall and red tile roof [9]. This process should be qualified as empirical since it continued to be informed by a traditional knowledge while still open to new materials (Fig. 3). The safe and good construction of buildings was then recognized as of the utmost importance in the 1882 building code. Numerous regulations were assembled in a code of construction that was partially applied and was prepared in Istanbul and designed for Beirut city was then based on principles which have been sufficiently amplified to provide for varying local conditions. The purpose of the Building Regulations in the past was to mitigate the health and safety risks of the dwellings that were being constructed to meet the needs of the industrial revolution. The byelaws, which set only basic standards for drainage, structure, fire spread, daylight and ventilation, were adopted and enforced in different ways. During the late Ottoman period, the quarter’s built fabric grew rapidly, vertically and horizontally. The vertical growth is evident from many existing single story houses that had additional floors added to them in the late 19th and early 20th centuries. In 1920, Beirut became the capital of Greater Lebanon and new materials such as concrete were employed, and methods of use have changed radically, so it was presented in this city as a substitute for a traditional one. In terms of building heights, concrete construction techniques became more complex during 1920s and allowed for taller buildings and at the same time houses became then street-aligned. Until 1920 the Ottoman building code still basically restricted building heights to a maximum of 18-21 meters (depending on the width of the street). During the French mandate period (1920-1940) building was erected to a height of 26 meters (Fig. 4). The basic approach of the Ottoman building code to control and regularize urban form by restriction, by defining minimum street widths, minimum setbacks and distances, and maximum building heights in relation to the streets, was altered by the new Building Code of 1920 [10]. It stipulated design standards to use in buildings and gives simple design rules for most masonry and timber elements for traditional domestic buildings. The Mandate State produces strategically road-infrastructure projects with tramway line that made changes in the demographic changes, and residential architecture [11].

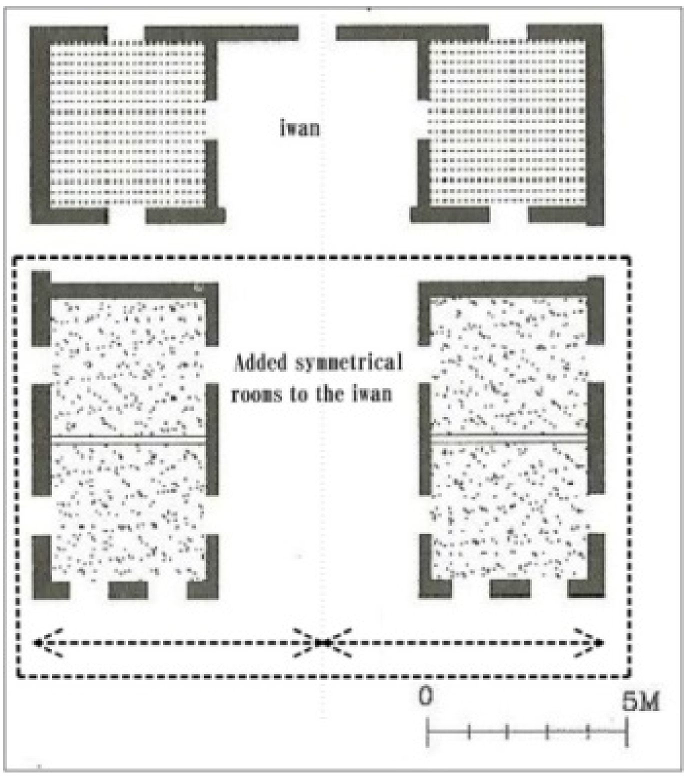

Fig. 3 The two symmetrical rooms were added to form traditional court as shown that was transformed later to covered hall. [9].

Fig. 4 To the left, type of Beiruti house (Late Ottoman period) consisting of two floors and roof frame of timber with red tile (1860). To the right, notice how buildings (French mandate period) changed radically as per heights affected by building code and regulations. (Hammoud J. 2016).

3. Analysis of the Application of Old Regulations or Codes in the Three Case Study Buildings

In 1896, the Beirut municipal engineer Amin Abd al-Nur edited and translated the 1882 Ottoman building code. In its first part, the construction law regulated the width of the streets; part two specified the procedures of street alignment. The following parts of the law were concerned with fire regulation and prevention, unifying the facades of houses facing the street, the norms for raising buildings, permissions, fees, prohibitions of restoration, registration fees, and penal codes [12]. The most parts that are useful for the construction system are the part 4, 5 and 6. Part 4 of the code, mentioned the limits of props and cantilevers extending over the straight line of the façade. Roads that are 12 cubits wide and above, a prop can be one cubit and a half (70 cm).

Roads that are 10 cubits wide shall limit the balconies to one cubit and a quarter. Article 27 from the code required that the covered and uncovered balconies constructed on the façade are not to be less than five cubits high from the surface of the road. The length of balconies should be two thirds of the facades on the road and must be straight. Article 29 requires the projection of doorsteps on the façade to be one carat (1.2 cm), while the projection of columns and terraces whether rounded or square must be two carats. Wooden or iron window frames and sashes must be four carats. The projection of rain gutters with their boxes, as well as shop extensions and facades made of glass, in addition to nets and iron frameworks placed on the windows of the lower floors and stores and the adornments placed on the doors of the stores must all be six carats (Fig. 5).

Part 5 of the code mentioned the heights of stone buildings; the height of any side of a building located either on the road or internally is 24 cubits which is 10.97 meters from the surface of the ground to the roof of the wooden closure.

Alleys of 12 to 15-cubit width (6.85 meters), the height of a building would be 28 cubits (12.8 meters). As for the hipped roofs and airplanes, their height shall not exceed six cubits (2.75 meters). In the case studies, we can notice that the height of the houses from street levels is almost near to the codes, but the hipped roofs exceed the measure required in the code (Fig. 6). The case of *Bchara el-Khoury* mansion is same as mentioned in the code where Buildings’ corners that are located on two roads of different capacity, its specified height measurement is related to the wider road which is 15 cubits (6.85 meters). It means that the height of the mansion can be 12.8 meters max. In this mansion and as shown in Fig. 7, the height is 12.9 meters from the ground which is almost the same as required. Measuring the height of the risers, shows an extra 1.2 meters from the street level that shall be added

Fig. 5 An example of props, projections and cantilevers in three buildings (Hammoud J. 2016).

Fig. 6 The height of the Kaaki house abide with the building height code but the height of the hipped roof exceed the required height (6 cubits = 2.75meters) (AbiRached E. 2016).

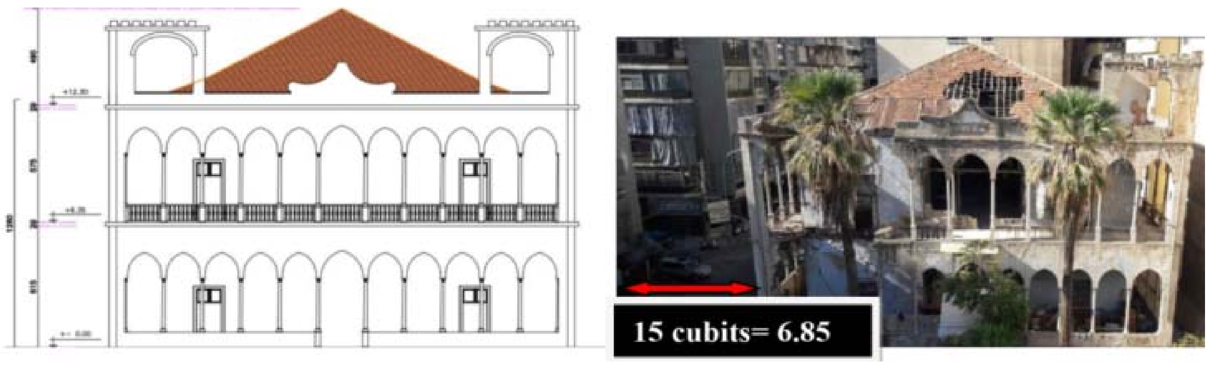

Fig. 7 The height is 12.9 meters from the ground which is almost the same as required in the code (AbiRached E. 2016).

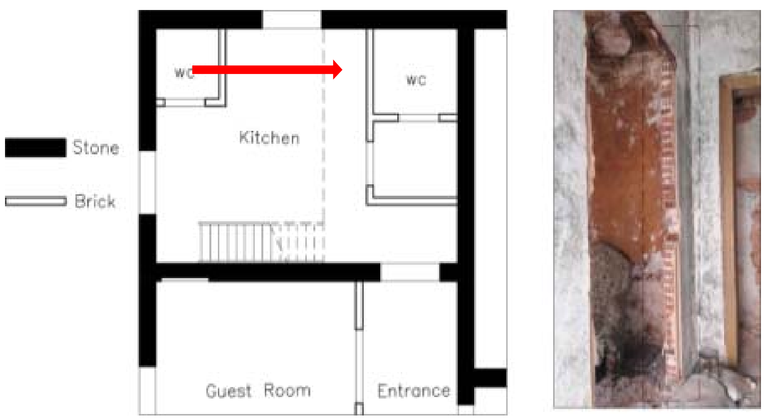

Fig. 8 Showing the materials used in the kitchen in Kaaki house abiding article 41 in the code (Hammoud J. 2016).

to the height, and then the total height does not comply with the codes. The height of the hipped roof is 4.9 meters that also exceeds the height required from the code. From part 6, Fire Prevention Measures, articles 38 and 41 mention that the stoves should be built from stone or bricks with an arch at the top and no kitchens may be allowed within the floors of wooden buildings. Kitchens usually were covered by stone vaulted ceiling at ground floors and brick or stone at upper floors (Fig. 8). From these analyses it can be concluded that the three case studies were complying the building code at the time.

4. Conclusion

Considering the relation of urban regulations and the transformation of urban space and construction in the late Ottoman period, allows us to comprehend that Beirut was far from being regularized at the end of the 19th century, displaying a vast architectural diversity, which stayed unchanged until 1940s due to the conflicts in the codes and the difficulties in the application and the lack of regulatory sanctions.

On the other hand, the structural strategy has evolved as a direct response to available material technologies, functional needs and guidelines from the building codes. This is evident in the way each primary material manifests itself in the building. The spatial planning of the house is a direct resultant of the structural system and together they form an architecture which is cohesive providing an understanding of the systems used in their making which represent the richness of Beirut heritage. The results of this research can aid future conservation efforts by passing new codes, as well as to encourage the conservation of these buildings which form an important link in the historic evolution of structure and the architecture of the region in its time-period.

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Modeling of Bridging Law for PVA Fiber-Reinforced Cementitious Composite Considering Fiber Orientation

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Abstract: The authors have proposed the calculation method of bridging law, that is expressed by tensile stress–crack width relationship, considering the influence of fiber orientation in FRCC (fiber-reinforced cementitious composite). The objective of this study is to propose a new tri-linear model that expresses the bridging law considering fiber orientation. The parameters that give the characteristic points of the tri-linear model are proposed as functions of orientation intensity. The bending test, in which the specimens are fabricated by three different casting methods, is conducted to verify the adaptability of the proposed model. The results of section analysis using the proposed model can present the difference of bending strength due to the fiber orientation.

Key words: FRCC, tensile stress, crack width, tri-linear model, fiber orientation, PVA fiber, bending test, compacting vibrator.

1. Introduction

FRCC (fiber-reinforced cementitious composite), in which short discrete fibers of a certain percentage in volume fraction are mixed in mortar or concrete, is cementitious material that shows higher tensile and bending performance comparing with conventional concrete. The elements such as coupling beams and seismic walls using SHCC (strain hardening cement composites), that show tensile strain hardening and multiple fine cracks, provide very ductile behavior with small crack opening (e.g. [1]). These characterized performances of FRCC are brought by bridging effect of fibers at cracks in the matrix. However, some previous studies have reported that the tensile characteristics even in SHCC are influenced by fiber orientation in matrix (e.g. [2]). Casting and pouring direction of FRCC affects the fiber orientation, and vertical pouring in tension test specimens causes degradation of tensile strength and deformation capacity of FRCC.

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The authors have studied the influence of fiber orientation to tensile characteristics of FRCC using PVA (polyvinyl alcohol) fiber through visualization simulation using water glass solution and calculation of the bridging law, which is expressed by tensile stress–crack width relationship [3]. To evaluate the fiber orientation distribution quantitatively, an approximation methodology using an elliptic function (elliptic distribution) was introduced in that study. The bridging law is calculated considering the elliptic distribution, the snubbing effect [4], and the fiber strength degradation [5]. The calculated bridging laws can show good agreements with the results of the tension test in which the specimens were fabricated by horizontal and vertical casting. However, it is difficult to use calculated bridging laws directly for evaluation of characteristics of FRCC elements such as beams and columns, because the shape of bridging laws which are expressed by tensile stress and crack width is strongly affected by fiber orientation. It is considered that simpler models for bridging laws make evaluations of FRCC elements easier.

Many types of tensile stress–crack width models for bridging laws can be considered. For example, multi-function models, multi-linear models, tri-linear models, and bi-linear models have been introduced for tensile stress–strain models of FRCC [2]. In this study, a tri-linear model shown in Fig. 1 is chosen to describe the characteristic points in calculated bridging laws considering the phenomena those occur in single fiber pullout properties. The modeled bridging laws are used for section analysis of bending test specimens to verify their adaptability. The modeled bridging laws are characterized by fiber orientation, so the bending specimens are fabricated by three casting methods to vary the fiber orientation.

At first, calculation method of bridging laws proposed by authors is briefly introduced in next chapter.

2. Calculation Method of Bridging Law

The authors have proposed the bridging law, which is expressed by tensile stress–crack width relationship, considering the influence of fiber orientation [3]. The bridging law is calculated by the summation of the pullout properties of each single fiber in crack surface. The model of the pullout load–pullout displacement relationship of the single fiber is shown in Fig. 2. The pullout load–pullout displacement relationship is modeled by tri-linear model considering chemical and frictional bond between PVA fiber and matrix [5]. At the time of the first peak load P_a, the chemical bond is debonded over the entire length of fiber. After that, the pullout load increases to maximum load P_{max} because of the frictional bond. The pullout load becomes zero when the crack width corresponds to the embedded length of the single fiber, l_b. The crack width at the first peak load, w_a, is twice the value of the pullout displacement, δ_{pull}. The crack width at the maximum load, w_{max}, is 1.5 times the pullout displacement because the pullout displacement on the end of long embedded length starts decreasing when the pullout load begins to decrease on the end of short embedded length.

The pullout property of single fiber varies due to snubbing effect and fiber strength degradation by orientation angle, ψ. Snubbing effect shows the increment of pullout load due to the reaction force at the embedding edge of fiber when fiber has orientation angle [4]. Fiber strength degradation shows the decreasing of fiber strength in the case of polymer fiber due to the surface of fiber roughed by the embedding edge when fiber is embedded obliquely with normal direction of crack surface [5]. As shown in Fig. 2, though the pullout load increases with increasing of orientation angle by the snubbing effect, fiber tends to rupture by the fiber strength degradation if orientation angle becomes large.

In order to give the orientation angle to each single fiber at crack surface in the calculation of the bridging law, a PDF (probability density function) has been proposed by Kanakubo et al. [3]. The PDF expresses the fiber orientation distribution using elliptic distribution. The fiber orientation varies by the value of orientation intensity k (ratio of the two radii of elliptic function) and principal angle θr (argument of

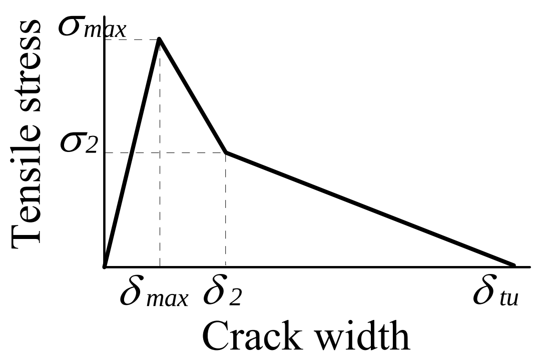


Fig. 1 Proposed tri-linear model for bridging law.

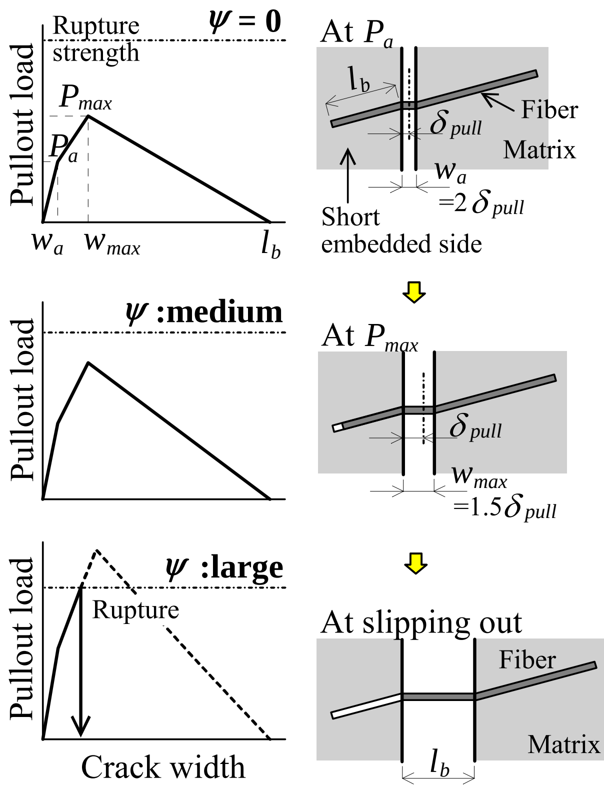


Fig. 2 Pullout model of a single fiber.

one radius of elliptic function). The random orientation is given by k = 1. When the value of k is larger than 1, fibers tend to orient toward θr. When the value of k is smaller than 1, fibers tend to orient toward the perpendicular to θr.

Tensile stress is calculated by the summation of the pullout load of each single fiber at crack surface as given in Eqs. (1) and (2).

$$\sigma_{bridge} = \frac{P_{bridge}}{A_m} = \frac{V_f}{A_f} \cdot \sum_h \sum_j \sum_i P_{ij}(w,\psi) \cdot p_{xy}(\theta_i) \cdot p_{zx}(\phi_j) \cdot p_x(y_h, z_h) \cdot \Delta\theta \cdot \Delta\phi \cdot (\Delta y \cdot \Delta z) \quad (1)$$

$$P = P_{pull} \cdot e^{f \cdot \psi} < P_{rup} \cdot e^{-f' \cdot \psi} \quad (2)$$

where,

σ_{bridge} = tensile stress;

P_{bridge} = bridging force (= total of pullout load);

A_m = cross-sectional area of matrix;

V_f = fiber volume fraction;

A_f = cross-sectional area of a single fiber;

P = pullout load of a single fiber;

P_{pull} = pullout load of a single fiber at a zero fiber angle;

P_{rup} = pullout load of a single fiber at rupture at a zero fiber angle;

F = snubbing coefficient;

f' = fiber strength reduction factor;

p_{xy}, p_{zx} = probability by elliptic distribution;

p_x = probability of fiber distribution along x-axis;

ψ = fiber angle to x-axis;

θ = angle between x-axis and projected line of the fiber to x-y plane;

ϕ = angle between x-axis and projected line of the fiber to z-x plane.

The PDF, p_x (y, z), gives the probability for the existence of the fiber in the x-axis direction. In this study, p_x (y, z) is assumed to be constant. This means that the fibers are randomly distributed along the longitudinal direction of the specimen.

The calculated bridging laws for the orientation intensity k from 0.1 to 10 are shown in Fig. 3. The parameters for the calculation are listed in Table 1. The principal angle θr is set to 0° (axial direction of the specimen). The curves in Fig. 3 do not include the crack strength to exhibit the stress due to only bridging force of fibers. As shown in Fig. 3, tensile stress significantly drops after the maximum stress, then moderate decrement follows. The significant drop and moderate decrement of the tensile stress in the calculation after the maximum stress is caused by rupture and pullout of fibers, respectively. The maximum tensile stress in the bridging law remarkably increases with the increment of the value of k, i.e., stronger fiber orientation to the normal direction of crack surface.

3. Modeling of Bridging Law

As described in the former chapter, the calculated bridging laws are strongly affected by fiber orientation. Proposing simpler models for bridging laws can make evaluations of FRCC elements easier. In this study, a tri-linear model shown in Fig. 1 is newly proposed to express tensile stress–crack width relationship of FRCC after first cracking considering the fiber orientation.

From Fig. 3, the bridging law is characterized by three parts, i.e., the part from the origin to maximum tensile stress, the part of the significant drop of tensile stress after maximum tensile stress, and the part of moderate decrement of tensile stress. Therefore, the tri-linear model of the bridging law is considered to be suitable as shown in Fig. 1. The model has five parameters: the maximum tensile stress, σ_{max}, the crack width at σ_{max}, δ_{max}, the second point tensile stress after the significant drop of stress, σ_2, the crack width at σ_2, δ_2, and the crack width at the loss of stress, δ_{tu}. δ_{tu} is constant value, because fiber is completely pulled out when crack width becomes half of fiber length.

Remaining four parameters in the model are expressed as a function of the orientation intensity k to simplify the modeling of the bridging law. The

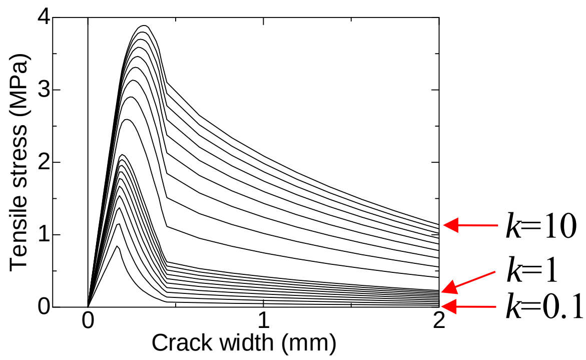


Fig. 3 Calculation result of bridging law.

Table 1 Parameters for calculation of bridging law.

Parameter	Input value
Fiber volume fraction, V_f	2.0%
Fiber length, l_f	12 mm
Fiber diameter, d_f	0.10 mm
First peak load, P_a	1.5 N
Crack width at P_a, w_a	0.20 mm
Maximum load, P_{max}	3.0 N
Crack width at P_{max}, w_{max}	0.45 mm
Fiber effective strength	569 MPa
Snubbing coefficient, f	0.5
Fiber strength reduction factor, f'	0.3

relationship between the parameters for stress and k are shown in Fig. 4. The relationship between the parameters for crack width and k are shown in Fig. 5. The dotted lines in all figures exhibit the regression calculation results for the values of the parameters by the least squares method. The solid lines exhibit the modified regression calculation result to simplify the relational expression between each parameter and k, and they are shown in each figure. The stress values in Fig. 4 are decided to be expressed by the function which starts from the origin because the bridging force becomes zero in the case of $k \rightarrow 0$, i.e., no bridging fiber exists. The function for δ_{max} is decided to pass the point of calculated value of δ_{max} at $k = 1$ (random orientation). From the calculation results of bridging law, δ_2 corresponds with the crack width at the maximum pullout load of single fiber in Table 1, i.e., constant value of 0.45 mm.

4. Bending Test of FRCC Varying Fiber Orientation

The bending test of PVA-FRCC is conducted to verify the adaptability of the modeled bridging law through section analysis. The bending test specimens are fabricated by three casting methods to vary the fiber orientation.

4.1 Specimens and Used Materials

The dimension of the specimens applied in this study is shown in Fig. 6. Specimens are the notched beams which have the cross-section of 100 mm × 100 mm and a notch with a depth of 30 mm and a width of 5 mm by a concrete cutter after FRCC become hardened. The position of a notch and a casting direction is as shown in Fig. 6. These dimensions and manufacturing procedures follow ISO 19044 [6]. The experimental parameter is the placing method of FRCC using the compacting vibrator explained after. Six specimens were manufactured for each parameter, and total of 18 specimens were tested.

PVA fiber of 0.10 mm diameter and 12 mm length were utilized in this study. The mix proportion of PVA-FRCC is shown in Table 2. The volume fraction of PVA fiber is 2.0%. FRCC in this study has self-compacting behavior. The average of compressive strength in the material age at bending tests was 34.6 MPa

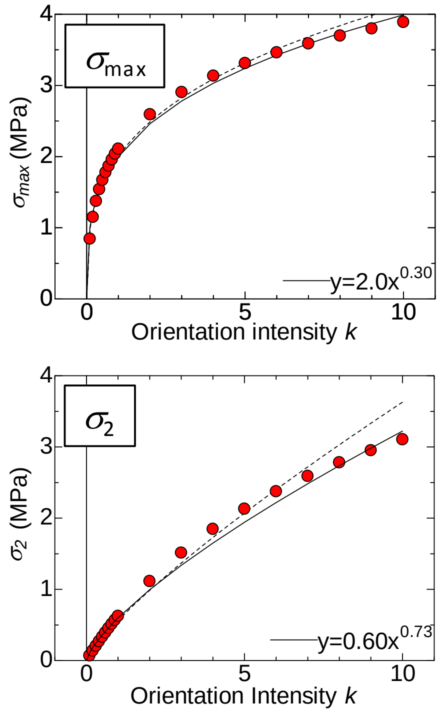


Fig. 4 Stress parameters for tri-linear model.

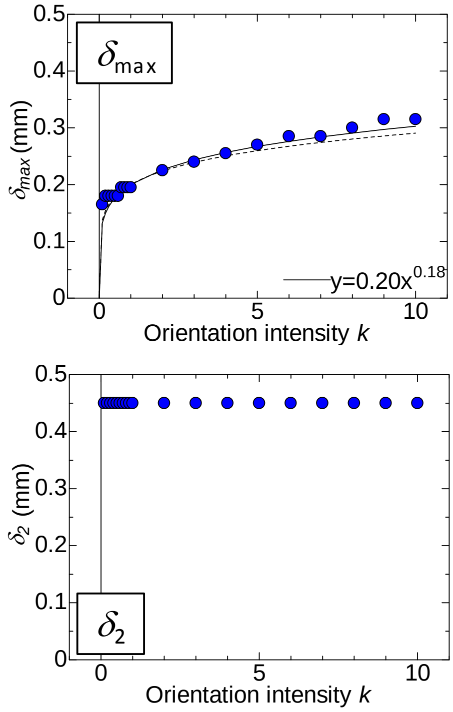


Fig. 5 Crack width parameters for tri-linear model.

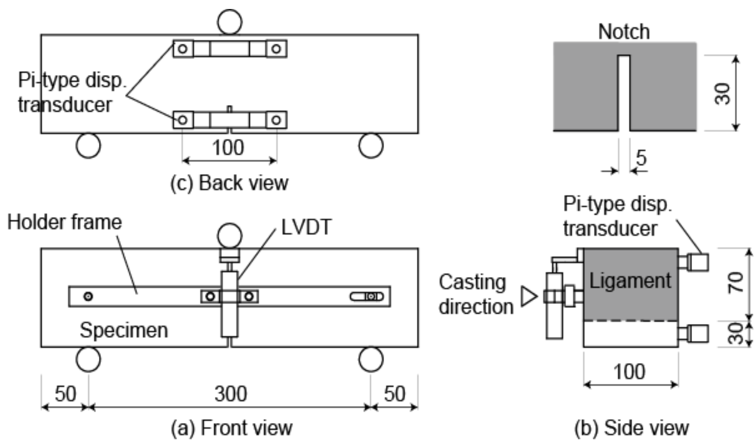


Fig. 6 Notched beam specimen for bending test (unit: mm).

Table 2 Mix proportion of PVA-FRCC.

Fiber volume fraction	Water by binder ratio	Sand by binder ratio	Unit weight (kg/m^3)			
			Water	Cement	Fly ash	Sand
2.0%	0.39	0.50	380	678	291	484

Cement: High early strength Portland cement, Fly ash: Type II of JIS A 6202.
Sand: Size under 0.2 mm, Super plasticizer: Binder × 0.6%.

by ϕ100 mm × 200 mm cylinder test pieces.

4.2 Placing of FRCC

Many researches have studied the effects of fiber orientation on the mechanical characteristics of FRCC, including FRC (fiber-reinforced concrete). The scheme of the current approach to evaluate the fiber orientation has considered the casting method, fresh-state properties, flow, vibration, and formwork geometry (e.g. [7]). The authors have studied the effect of a compacting vibrator to bending characteristics of FRCC beams [8]. The bending capacity and ductility increases by applying a compacting vibrator after pouring FRCC. It is suggested that the fiber orientation tends to differ in each specimen by observing the specimen sections after loading. So, the method of applying a compacting vibrator is also introduced in this study to vary the fiber orientation of specimens.

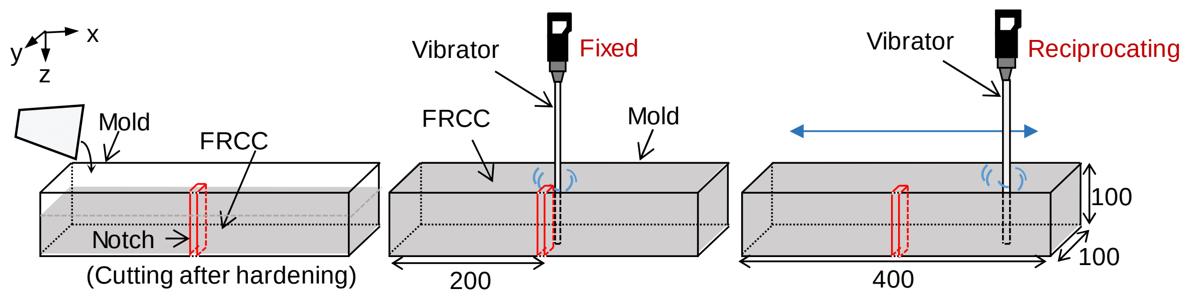
Fig. 7 shows the three series of compacting methods of FRCC: (a) SC (self-compacting) without vibrating; (b) VF (vibrator-fix); and (c) VM (vibrator-move). A vibrator with a 24.5 mm diameter rod, and vibrating frequency of 200 Hz, which is commonly used for compacting of conventional concrete, was used.

SC is standard placing method in which FRCC is continuously poured from the edge of the mold with the slope of 1/33. In VF compacting, the vibrator is set with vibration at the center of the specimen after FRCC is poured into the mold. The vibration period is 10 s. VM compacting is the method in which the vibrator is moved and reciprocated with vibration from the end of the mold to the other end after FRCC pouring. The vibration period is also 10 s.

The examples of photos of the specimens of VF and VM are shown in Fig. 8. As shown in Fig. 8, in the case of VF, FRCC matrix showed a circular motion with a central focus on the vibrating rod, i.e., fibers tend to orient concentrically. In the case of VM, FRCC matrix flowed longitudinally following movement of the vibrating rod. These observations indicate that fibers in FRCC tend to orient toward the axial direction along the flow.

4.3 Method of Loading and Measurements

Fig. 9 shows the bending test setup. Three-point bending tests were conducted based on ISO 19044 [6] using the displacement controlled universal loading machine of 2,000 kN capacity. The speed of the cross-head was set to 0.5 mm/min. Measurement items were load, axial deformation in central part of the specimen (gauge length = 100 mm) using two pi-type displacement transducers, and the LPD (loading



(a) SC (self compacting) **(b) VF (vibrator-fix)** **(c) VM (vibrator-move)**

Fig. 7 Compacting method (unit: mm).

(a) VF (vibrator-fix) **(b) VM (vibrator-move)**

Fig. 8 Manufacturing and vibrating of specimen.

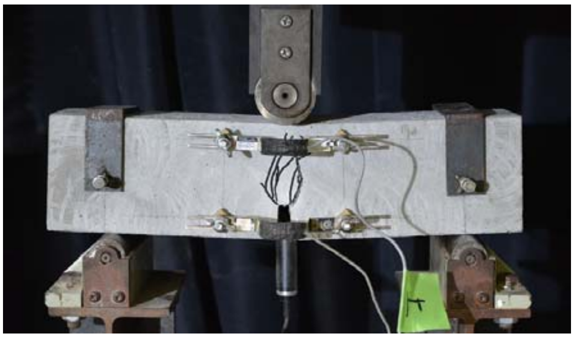


Fig. 9 Bending test setup.

point displacement) using a LVDT as shown in Fig. 6.

4.4 Test Results

The examples of the specimens of each placing method after loading are shown in Fig. 10. All specimens had plural cracks and fractured with localizing the opening of one crack after maximum load. In the case of SC specimens (self-compacting), rectilinear cracks took place perpendicularly to axial direction of the specimen. In the VF specimens (vibrator-fix), curved cracks were observed. It is considered that the curved cracks occurred due to the fiber orientation like concentric circles centering the point of vibrating. This assumes that cracks tend to progress along the weaker parts in the matrix, in which fibers orient toward crack direction and weaker bridging effect provides. In the case of VM specimens (vibrator-move), there were more cracks than those in the specimens SC and VF. It is suggested that the tendency of fiber orientation toward the axial direction in the VM specimen causes more cracks by stronger bridging effect.

Fig. 11 shows the load–CMOD (crack mouth opening displacement) curves of all specimens. CMOD was calculated as the axial deformation at the undersurface of the specimen from the measured axial deformation by pi-type displacement transducers. The points of the maximum load are plotted by circles. As shown in Fig. 11, load gradually increased after first cracking in all specimens. After the peak load, the load slightly decreased with the repetition of increase and decrease of the load. Table 3 shows the summary of the bending test results. Fracture energy in Table 3 is calculated by the following Eq. (3).

$$G_F = \frac{W}{A_{lig}} \tag{3}$$

where,

G_F = fracture energy;

W = area below load–LPD curve up to 15 mm;

A_{lig} = area of ligament.

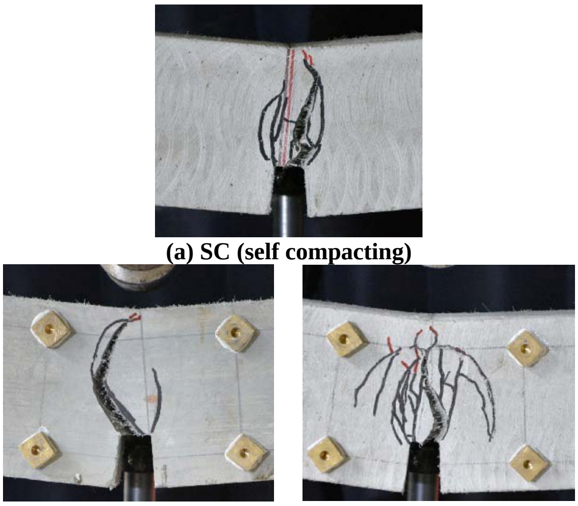
The maximum loads of the VM specimens are twice larger than those of the SC specimens, and the fracture energies of the VM specimens are largest of all. It is considered that the bridging effect is improved by moving a vibrator. In the case of the VF specimens, the maximum loads show larger scattering comparatively.

5. Adaptability of Modeled Bridging Laws

The modeled bridging laws are used in section analysis to verify their adaptability through the evaluation of bending strength of the specimens explained in former chapter.

5.1 Section Analysis

In order to evaluate the bending strength, the section analysis based on the modeled bridging law is conducted. Fig. 12 shows whole stress–crack width model applied for the section analysis. The tensile stress–crack width model is the tri-linear model proposed in this study expressed as the functions shown in Fig. 4 and Fig. 5. The compression side is assumed to keep elasticity. The section analysis is carried out based on the assumption that plain section



(a) SC (self compacting)

(b) VF (vibrator-fix) (c) VM (vibrator-move)

Fig. 10 Examples of specimens after loading.

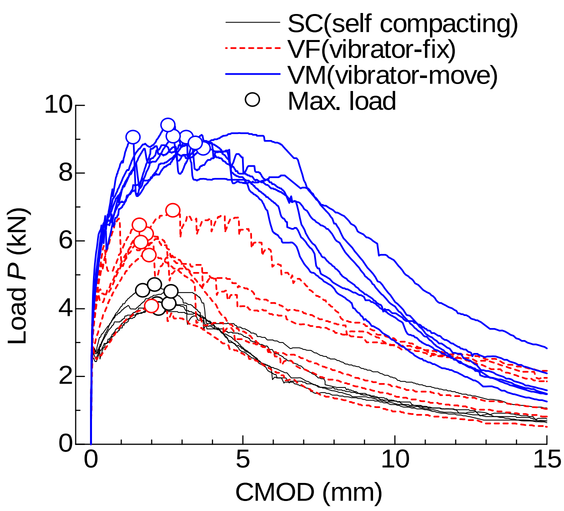


Fig. 11 Load–CMOD curves.

remains plain under considering the plain section's deformation. Firstly, arbitrary angle of rotation is given. Secondly, the crack width of each element in cross-section is calculated from linear distribution of deformation and the stress in each element of cross-section is obtained from Fig. 12. Finally, neutral axis satisfying equilibrium condition is found numerically and bending moment is calculated. The section analysis is conducted by varying orientation intensity k in the bridging law model.

The compressive stress–compressive deformation model is elastic based on the compression test results of cylinder test pieces. However, compressive strain instead of deformation is obtained from the compression test. In order to convert the strain into the deformation, equivalent compressive length $l_{c,eq}$ is introduced. The equivalent compressive length is determined to fit the initial slope between the result of section analysis and measured load–CMOD curves in the bending test. The stiffness in compressive stress–compressive deformation model is given by elastic modulus measured in compression test (E_c) divided by $l_{c,eq}$.

5.2 Comparison of Analysis and Test Results

The comparison of the maximum bending moment between the results of section analysis and bending

Table 3 Bending test results.

Placing method	ID	At maximum load		Fracture energy (N/mm)
		Max. load (kN)	CMOD (mm)	
	SC-1	4.53	-	4.15
	SC-2	4.14	2.19	3.58
	SC-3	3.99	2.24	3.47
SC	SC-4	4.14	2.58	3.17
	SC-5	4.50	2.65	3.26
	SC-6	4.70	2.11	3.51
	Average	4.33	2.35	3.52
	STDV	0.28	0.24	0.34
	VF-1	6.20	1.84	4.46
	VF-2	6.46	1.61	4.21
	VF-3	5.95	1.66	4.46
VF	VF-4	6.89	2.71	7.65
	VF-5	5.57	1.93	4.24
	VF-6	4.07	2.01	3.02
	Average	5.85	1.96	4.67
	STDV	0.98	0.40	1.55
	VM-1	9.05	1.40	10.2
	VM-2	9.05	3.15	9.01
	VM-3	9.08	2.72	8.20
VM	VM-4	8.72	3.71	8.69
	VM-5	9.41	2.55	9.74
	VM-6	8.88	3.45	7.03
	Average	9.03	2.83	8.81
	STDV	0.23	0.82	1.13

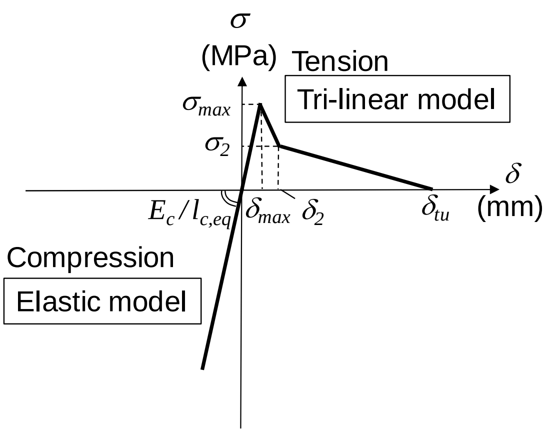


Fig. 12 Stress–crack width (deformation) model for section analysis.

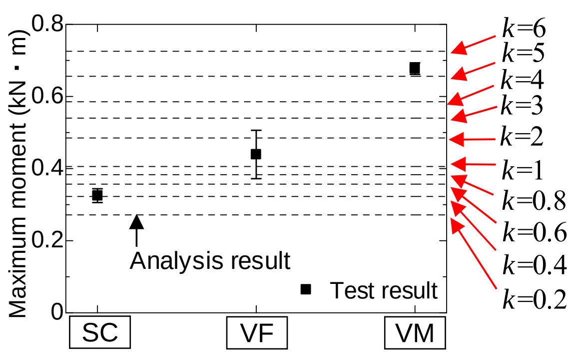


Fig. 13 Maximum bending moment by section analysis and bending test results.

test is shown in Fig. 13. The dotted lines indicate the maximum bending moment calculated by section analysis using each orientation intensity k from 0.2 to 6. The average maximum bending moments in the bending test are plotted by squares with error bars (standard deviation). As shown in Fig. 13, the analysis results in the case of k = 0.4, k = 1, and k = 5 show good agreements with the test results of the SC specimens, VF specimens, and VM specimens, respectively. The difference of bending strength due to the fiber orientation is expressed by the section analysis using the bridging law considering fiber orientation.

6. Conclusions

The authors have proposed the method of calculation of bridging law, which is expressed by tensile stress–crack width relationship, considering the influence of fiber orientation. The calculated bridging law is strongly affected by fiber orientation, which is featured by orientation intensity k. A tri-linear model is newly proposed to express the tensile stress–crack width relationship considering the fiber orientation. Through the bending test, in which the specimens were fabricated by three casting methods to vary the fiber orientation, the followings are found out:

(1) The parameters that give the characteristic points of the tri-linear model are proposed as functions of orientation intensity k.

(2) The maximum loads of the VM specimens (a compacting vibrator is reciprocated longitudinally after FRCC pouring) are twice larger than those obtained by SC specimens.

(3) The results of section analysis, which is conducted to verify the adaptability of the proposed model, can present the difference of bending strength due to the fiber orientation.

Acknowledgments

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Effective Offshore Piling Noise Mitigation in Deep Waters

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Abstract: Underwater noise is a severe annoyance and danger to marine life. The innovative HSD (hydro sound damper) leads to an effective general method to reduce underwater noise. HSD was developed and patented between 2007 and 2010 by the author to reduce general marine noise and especially offshore piling noise. The theory and the acoustical background of the new noise mitigation method will be presented. HSD systems use nets with gas filled elastic balloons and special PE-foam elements with high dissipative effects to reduce continuous and impact noise. The resonance frequency of the HSD-elements, the optimum damping rate for impact noise, the distribution and the effective frequency range can be fully controlled. Offshore tests and serial applications in offshore wind farms in Germany and Great Britain demonstrate this new effective way to reduce the very high offshore piling noise. HSD systems are very small systems and easy to handle. They are independent of external air supply, not influenced by tidal currents, not expensive and easy adaptable to different applications. Underwater noise reductions by HSD systems and bubble curtains are measured by an independent acoustics institute when using the biggest hammers in the world. Achieved results between 14 dB (decibels) (SEL—sound exposure level) and more than 27 dB (SEL) are presented and discussed.

Key words: Wind turbines and windfarms, transient or impulsive noise, scattering, resonant absorbers, construction noise, underwater noise mitigation.

1. Introduction

Hydraulic impact hammers induce considerable underwater sound emissions. The construction noise of offshore wind turbines is potentially harmful to marine life. Different zones of underwater noise immissions can be defined in the surrounding of an acoustic noise source of about 30 km and more [1].

Due to today larger piles requiring higher driving energies, even higher underwater noise levels are expected in future projects, accompanied by an increasing number of wind turbines. Effective noise reducing methods are in great demand, getting sound levels below recommended acoustic emission thresholds that are no longer harmful or disturbing to marine life [2].

1.1 Underwater Piling Noise Measurement

Underwater piling noise is usually described by two sound levels [3]. The first level is the peak SPL (sound pressure level) in dB (decibels) of the maximum instantaneous pos. or neg. sound pressure $|p_{peak}|$ of the measured impact noise that is referred to the underwater sound pressure of $p_0 = 1$ μPa:

$$peak\ SPL = 20\log\left(\frac{|p_{peak}|}{p_0}\right) \tag{1}$$

The second level for describing pile driving underwater noise is the SEL (sound exposure level) in decibels (e.g. dB re:1 μPa^{2}s), which is an equivalent energy level of the noise of a single pile driving impulse, based on $T_0 = 1$ s:

$$SEL = 10\log\left(\frac{1}{T_0}\int_{T1}^{T2}\frac{p(t)^2}{p_0^2}dt\right) \tag{2}$$

The SEL is the level of a continuous sound with 1 s duration and the same sound energy as the pile driving impulse.

Measurements of underwater piling noise show peak levels of more than 210 dB (SPL) and sound exposure levels of more than 180 dB (SEL) at 750 m distance from pile driving sites, depending on ram energy and pile size.

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1.2 Standard Levels of Underwater Piling Noise

The BSH (German Federal Maritime and Hydrographic Agency) has set the standard sound exposure level of 160 dB (SEL) and the peak level of 190 dB (SPL) at 750 m distance from offshore pile driving sites as part of the building permission of offshore wind farms. Effective noise reducing methods are necessary to achieve these standard levels.

Offshore applications of air bubble curtains are expensive at big water depth and currents. The main problems are the compressed air supply, the control of the bubble size, the installation of air pipes on the ground and the influence of water currents together with slow ascent rates of the bubbles.

2. Theory of HSD (Hydro Sound Damper)

To overcome these problems, a new underwater noise reducing method is developed, using gas filled enveloped bodies and PE-foam elements as hydro sound dampers, instead of free air bubbles.

In contrast to conventional air bubbles, HSDs of both kinds, gas filled bladders and PE-foam elements allow to use three different physical effects for underwater noise attenuation:

- Reflections of sound waves at impedance steps from water, filled with hydro sound dampers;
- Resonance effects with high scattering, multiple reflections and absorption of sound waves;
- Dissipation of acoustic waves according to material damping effects of HSD elements.

The important resonance effects with high scattering, multiple reflections and effective absorption of sound waves in water are shown in Fig. 1. There is to be seen a very strong interaction of a vibrating HSD-element at the surrounding water surface. This interaction also takes place around HSD elements under water, but it is not visible there.

The size of the bodies, the effective frequency range, the selected material and the damping rate, the number and distribution of the HSD and the influence from hydrostatic pressure can be fully controlled, if the envelope bodies are fixed to a pile surrounding fishing net after Fig. 2 or to stiff frames.

HSD is used in the whole frequency range of pile driving noise. Special types of materials and elements are developed to optimize absorption and damping effects. Finally, HSD elements do not need compressed air supply.

3. Noise Mitigation Test of HSD

For a first offshore test during pile driving in the German Baltic Sea a prototype of the HSD system was a self-swimming construction with winches to lower three different types of HSD nets to seabed [4]. All elements of the same size were tuned to the resonance frequency of 120 Hz to get reduced noise transmissions in a very effective way within the most important lower frequency range around 120 Hz.

The radiated underwater sound pressure was measured at 4 m above the ground at a distance of 6 m from the pile to get most of the directly radiated noise and to avoid influences from the water surface and

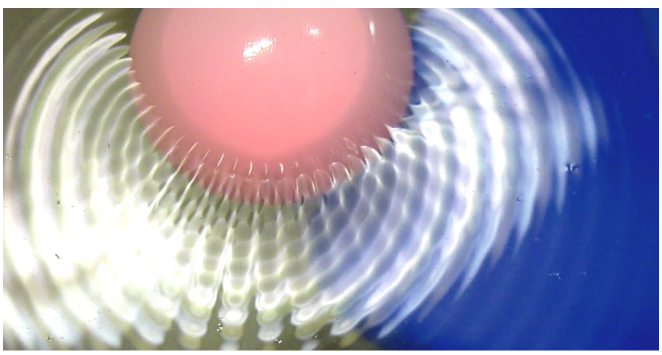

Fig. 1 Scattering, radiation and interaction [2].

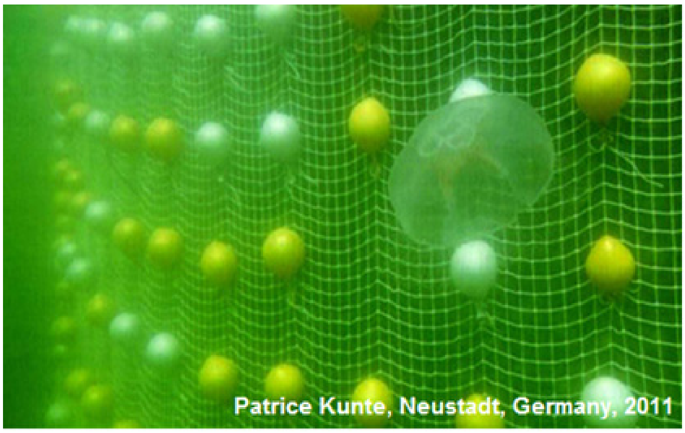

Fig. 2 HSD net and elements under water [3].

from the sea ground. Fig. 3 shows the 1/3 octave SEL spectrum of the original piling noise and the reduced sound exposure level after applying HSD noise mitigation of both, gas filled balloons and PE-foam element.

The measured underwater noise mitigation of about 23 dB (SEL) means that 99.5% of the whole sound energy is damped out by the HSD net after Fig. 2.

This result is very interesting, as the used HSD-net is only covered by HSD-elements at about 5-10% of the net surface. Thus, the measured results show, that it is possible to realize a screen of more than 90% permeability to current water and to water waves, but at the same time building an impermeable barrier to underwater noise of up to 99.5% of the noise energy.

This result is very remarkable as it is well known from acoustics and sound isolations, that already a small opening of 5-10% of the isolation like a tilted window breaks down the whole effect of sound isolation. The opening of the HSD-net is more than 90% of the net surface where water can flow through it.

4. Offshore Applications of HSD Systems

During pile driving of big monopiles into the sea ground sound waves are not only radiated into the surrounding water. There are also radiations of vibrational waves from the pile surface deep into the layered ground. Parts of these waves can reach the surface of the sea ground and induce additional sound waves in the water, far away from the piling site. To reduce this indirect underwater noise, additional bubble curtains are used at a distance of 100 m around the piling site.

4.1 HSD-System

The whole HSD system with the HSD net around a pile, the HSD-box on the sea ground as the counterweight to the buoyancy forces of the net and the steel wires with the winch frame are visualized in Fig. 4.

4.2 HSD Net and HSD Box

The HSD net is fixed to the ground of the HSD box and folded in this basket for transport. Before piling the HSD box is set around the pile while hanging below the PGF (pile guiding frame) of the installation vessel after Fig. 5.

For piling the HSD box with the net inside is lowered to the sea ground while the net is fully extended around the pile from the sea ground up to the water surface after Fig. 6.

In Fig. 7 an installation vessel with piling device and HSD system of an offshore project is shown.

Comparable to the situation in Fig. 6 the net box is laying on the sea ground, the net is expanded around the pile and swimming up to the surface of the water. The HSD system is hanging below the winch frame (blue device) that is situated below the pile gripper frame PGF (green device) of the installation vessel for

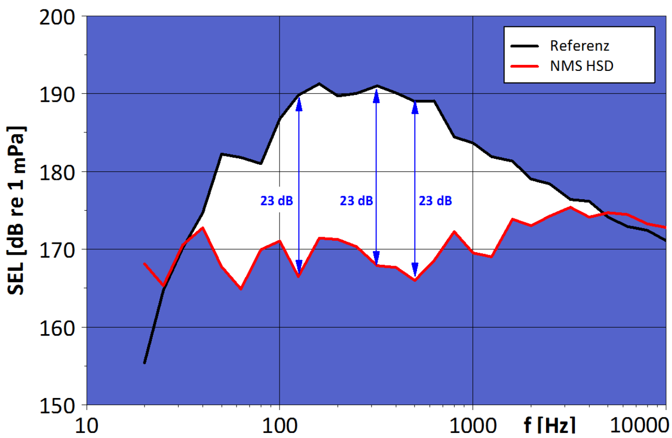

Fig. 3 Third octave SEL spectra of underwater piling noise w/o HSD noise mitigation [4].

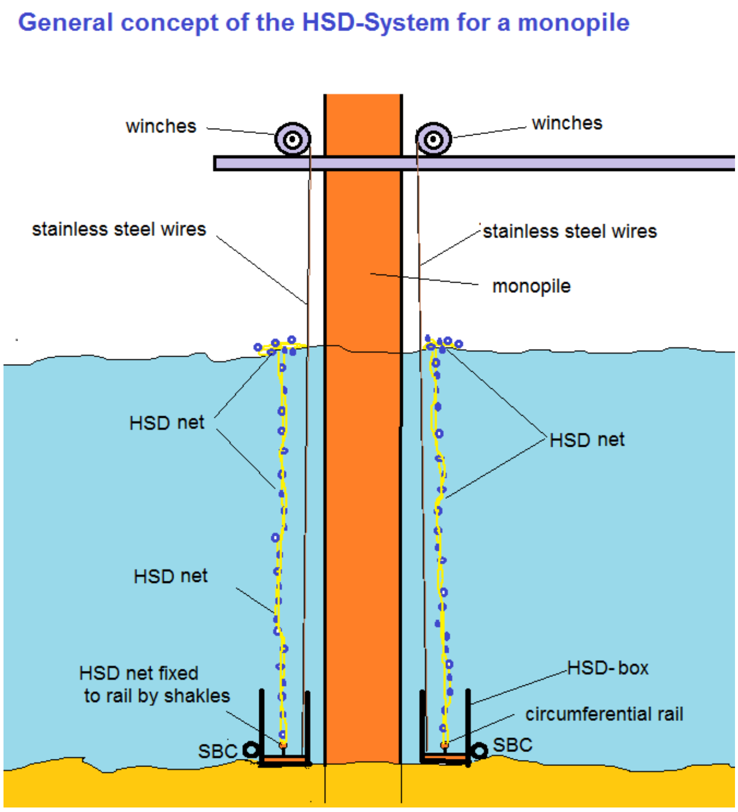

Fig. 4 HSD-system with HSD-net around a pile and with HSD-box on the ground [5].

precise positioning of the monopile. The hydraulic hammer (yellow) on top of the pile is the Menck MHU 3500S with up to 3500 kJ.

5. Achieved Noise Mitigation of HSD Systems

The HSD system was located on a separate winch frame (blue device) below the PGF in Fig. 7. With this solution the net box was controlled in parallel to other works of the main hook which caused not any time delay and deck space for the HSD noise mitigation. The resulted noise mitigation of the Offshore Windfarm "Sandbank" (2015) in the German North Sea using a HSD-System in combination with a double big bubble curtain was between 19-27 dB (SEL) after Table 1.

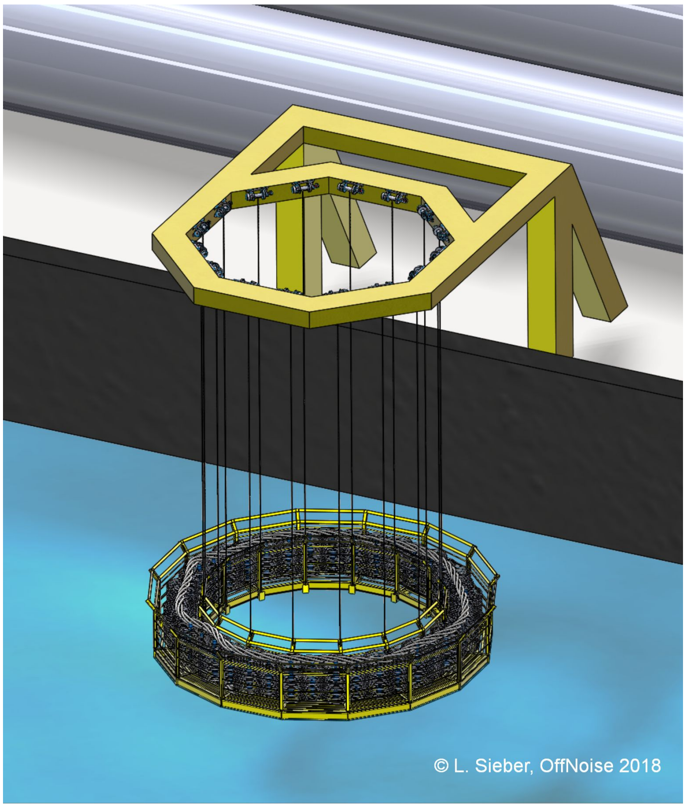

Fig. 5 HSD-Net folded in a basket before piling.

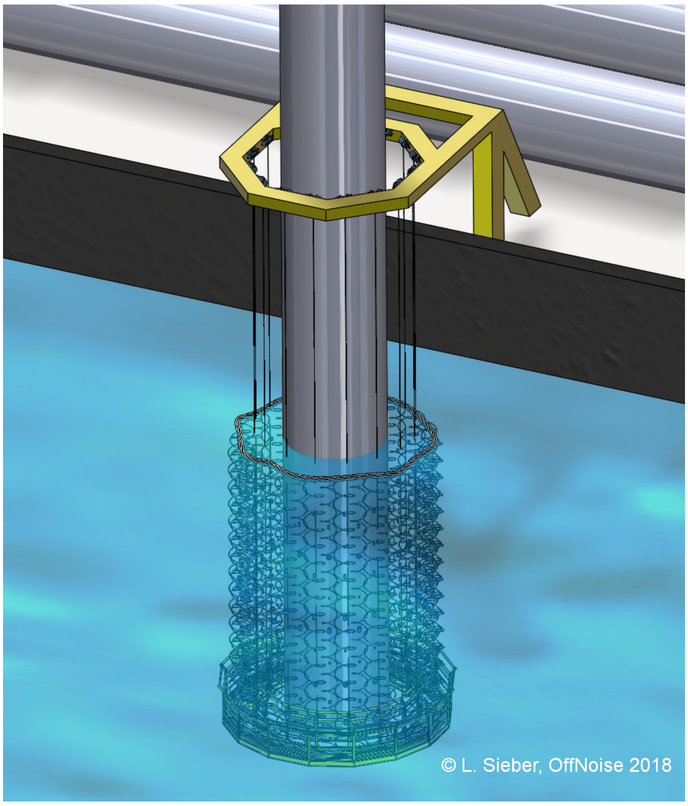

Fig. 6 Box on the ground; Net is fully expanded.

Fig. 7 Expanded HSD net for 40 m water depth.

Table 1 Developing process of HSD systems.

Offshore Wind Farm	Amrumbank	Sandbank	Veja Mate	Wikinger	Arkona
Year	2012	2014-2015	2016	2016	2017
Foundation	Monopile	Monopile	Monopile	Jacket, prep.	Monopole
Pile diameter	6.0 m	6.8 m	7.8 m	2.7 m	7.8 m
Water depth	25 m	34 m	40 m	40 m	40 m
Hammer type	MHU 1900S	MHU 3500S	IHC S-4000	MHU 1200S	IHC S-4000
HSD implementation	Connected to hammer	Separate frame	Separate frame	Separate frame	Openable net box
Noise reduction, dB (SEL) Using HSD + DBBC	$14 \le 16 \le 22$	$19 \le 22 \le 27$	$18 \le 20 \le 24$	Not published	Not yet published

6. Results and Discussions

The innovative HSD is a cost-effective method of attenuating underwater piling noise in offshore marine piling projects. HSD is also applicable as an effective general method for reducing any kind of underwater noise and piling noise in ports and harbors. HSD achieves high reductions even in the presence of strong tidal currents or rivers. In combination of HSD systems with DBBC (double big bubble curtains) noise mitigations are measured between 19 and up to 27 dB (SEL). HSD systems are small and easy to handle and are patented in several countries [6].

7. Conclusions

The use of HSD will significantly reduce the observation area required during piling operations and provide improved protection of the marine environment from potential adverse impacts upon marine life from impulsive and cumulative underwater piling noise exposure [1].

HSD elements are optimal tuned to special low frequencies of the noise spectrum of today's big hammers, of future piles of more than 10 m diameter and of water depths of up to 40-60 m.

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Qualitative Analysis of the Management of Three Public Universities in the State of Minas Gerais—Brazil

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Abstract: Many Brazilian federal universities do not make use of a concrete and effective maintenance policy of its public buildings. Taking this fact into consideration, the objective of this work is to contribute with an assessment of the current maintenance management carried out in three federal universities in the State of Minas Gerais: the UFOP (Federal University of Ouro Preto), UNIFEI (University of Itajubá) and the UFMG (Federal University of Minas Gerais). These universities were chosen because they have buildings with metal structures and also for being a reference in the state of Minas Gerais, which is the largest steel producer in Brazil. Knowledge was sought about the management of the campus infrastructure maintenance by raising questions about the main tools used by managers and other professionals in the field. The adopted methodology was qualitative and performed through semi-structured interviews conducted via email, with servers working directly or indirectly within each building maintenance system. The results show lacking a well-formulated plan and building maintenance programs as well as a specialized and qualified skilled labor force for the performance of services.

Key words: Building maintenance, management, public buildings, life cycle.

1. Introduction

It is true to say that some maintenance activities could be prevented if everyone involved in the construction process were committed to the quality of the final product. Nevertheless, there is not a single building that is free from the depreciation process and the natural wear and tear of the materials used to build it. Some maintenance activities are inevitable and should be oriented towards delivery of the completed building completed and should have an accompanying technical support system for the maintenance and upkeep of the structure in question [1].

Maintenance is defined by the Rule NBR 14037 [2], as the set of activities to be undertaken to preserve or restore the functional capacity of the building and its constituent parts in order to meet the needs and safety of its users.

The planning of maintenance services requires the preparation of a detailed forecast of working methods, tools and equipment, special conditional access, development schedule and duration of maintenance services according to the recommendations of NBR 5674 [3].

Failures of maintenance affect the technical, operational and administrative aspects; however, the greatest problem is the lack or inadequacy of the building's maintenance plan.

According to Moraes [4], in the planning process, the maintenance priorities are determined, thus evaluating existing conflicts between minimizing costs, maximizing building performance while minimizing the risk of failure. At this stage, information is generated to create the maintenance plan, which is key to programming and recording future activities.

With all information identified and the necessary

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documentation implemented, the maintenance plan must then be computerized for the control of the entire team. The programming is generated with the schedule and recording of activities for a certain period of time.

According to Silva [5], one only manages what one knows. The lack of a database makes the manager follow any path, which is not always effective, especially in times of economic crisis, where financial resources are increasingly scarce. Technical reports should be made available to all involved in the project and, vitally, at times of decision making.

The management evaluation strategy of building maintenance must follow the following steps: inspection; identification of the type of maintenance strategy; verification of the coherence of the identified strategy with the expectations of its users; execution of building inspection for verification of non-compliance techniques of use and maintenance; documentation analysis for the building to complement data provided by the inspection and elimination of errors in maintenance contracts with subcontractors; assessment of the maintenance team and their training; design and ability to meet certain actions; evaluation of the maintenance costs; and, finally, appraising the quality of the service provided [6].

According to Carlino [7], when trying to understand the difficulties of public administration, it is necessary to reflect on some issues such as: (a) How to treat the maintenance of public buildings so that they can be preserved and not depreciate over time? (b) How to develop a focused building maintenance plan for continuous improvement and shift of paradigms that satisfactorily meets employees' demands in their daily activities and others who enjoy the services provided in these buildings? (c) How can the quality of service and preservation of public property with features not always available be maintained when the number of staff is constantly decreasing?

In Malaysia between 2006 and 2009, it was reported by Lateef et al. [8] that more than 14 billion USD were allocated for the construction and maintenance of its public universities.

Maintenance costs are a significant part of the operating cost. For example, the amount spent on maintenance budget in Europe is around 1,500 million euros per year [9]. Today, it is accepted that maintenance is a key function to sustain the long-term profitability of organizations.

The maintenance of new buildings, renovation and modernization of older constructions require considerable experience and commitment of human and material resources. This is because the changes in climatic conditions and a lack of maintenance culture are responsible for aging and deterioration of buildings and educational equipment [10]. However, most managers and educational managers who constantly use the educational facilities do not have the maintenance planning knowledge of these facilities.

Sangjun and Yukio [11] showed that studies on the management and maintenance of facilities have increased in Japan, but that there is still a lack of government initiatives for the maintenance of public facilities.

Estermann and Pruvot [12] stated that financial sustainability will be a major challenge for universities in the next decade: only those institutions that have a solid and stable financial structure in their income stream will be able to fulfill their mission in responding to the current challenges in an increasingly complex and global environment.

2. Methodology

When it comes to mining, the first reference is well defined in the state of Minas Gerais. It is in this state where there are the most concentrated steel factories and the higher production of steel in Brazil. Due to this high-concentration area, three federal universities were chosen because of their great importance in the mining industry: the UFOP (Federal University of Ouro Preto), UNIFEI (University of Itajubá) and the UFMG (Federal University of Minas Gerais), the largest in the state. All these universities have buildings with different building typologies, among them buildings with metal structures. This object points to a methodological approach to qualitative research. During the case studies, two basic sources of information were used: semi-structured interviews and documentary analysis (GODOY, 1995; LAVILLE and DIONE, 1999) [13, 14]. The interviews were conducted via email with the officials responsible for the infrastructure maintenance sector of the universities studied from August 2015 to April 2016.

3. Results

3.1 UFOP

The UFOP was established on August 21, 1969 from the merger of two century-old institutions of higher education: the School of Pharmacy founded in 1839 and the School of Mines founded in 1876, both located in Ouro Preto, Minas Gerais.

Among the buildings that are part of the UFOP, those with the different typologies cited are the School of Pharmacy and the School of Mines (Figs. 1 and 2).

Currently UFOP has a maintenance department, located next to the campus town hall, which is responsible for receiving requests and delegating services containing a specific order of priority. Usually, the department head makes the requests of different needs such as spare bulbs, the installation of partitions, room painting, closing walls and so on. They refer to the maintenance department that scrutinizes the availability of staff to deliver the services and the material needed in the warehouse.

Fig. 1 Pharmacy School.
Source: Íris Jesus—Collection UFOP, 2015 [15].

Fig. 2 School of Mines.
Source: Íris Jesus—Collection UFOP, 2015 [16].

As stated by the officials interviewed, the university does not have any preventative maintenance services, but only corrective maintenance when the services are repaired as a consequence of an existent issue.

Therefore, there is no policy and no prior planning of the activities that has taken place over the years; it is known that a light bulb will reach the end of its life expectancy, but it is uncertain to define when, how or even which parameters to establish if there is also a problem in the electrical network.

The UFOP maintenance services include the buildings of the campus itself, Morro do Cruzeiro, the buildings of the city center of Ouro Preto (i.e. the School of Mines, the Pharmacy School, the Cine Vila Rica Theater, the Convention Center, all the Federal University Residence Halls and the IFAC—Institute of Philosophy of Arts and Culture) in addition to the University Campus in the cities of Mariana (ICHS and ICS) and in João Monlevade.

According to the staff of the maintenance department, inventory control is performed through spreadsheets and then published on the university website. In reality, there is no control of the service demand. It is clearly uncertain to specify which buildings request an upgrade or repair service or if any of the buildings has placed more repair services than others, or if the requests are repetitive or from the same period.

The maintenance applied to the UFOP buildings has basically an emergency character, correcting repairs presented in the final degree of an emergency, earning the title of “very urgent”. Even though some buildings present visible issues, the school managers do not raise these issues, because there is no systematization program for the needs and building maintenance; therefore, the issues are not eliminated.

3.2 UNIFEI

On November 23rd, 1913, the UNIFEI was founded under the personal initiative of lawyer Theodomiro Carneiro Santiago with the original name of IEMI (Electro-technical Institute & Itajubá Mechanics). It was the tenth School of Engineering founded in Brazil at the time. The federal government officially recognized the Institute on January 5, 1917.

The Laboratory Building with its conventional masonry and the metal-structured building, both located in the Campus of Itabira, are among the buildings of the Federal University of Itajubá with different building typologies (Figs. 3 and 4).

The Maintenance Building Division is subject to the Town Hall of Itajubá and the UNIFEI Dean of Administration. The Division currently has a staff of skilled employees and specialized contractors in their areas of competence who carry out maintenance activities on the campus.

How the UNIFEI corrective maintenance is applied is also noteworthy. Such maintenance occurs using the virtual platform “Ocomon”, i.e. occurrences monitor and computer equipment inventory. When a server detects a problem, the server logs onto the platform, selects the sector responsible for the problem area, types the issue area (e.g. constructive pathology, change furniture, etc.) and then “opens” a call for maintenance, describing concisely what was observed along with any criticisms and suggestions.

The outsourced services are surveillance, cleaning of the buildings, catering, and the provision of various other services. Among the services offered by the university maintenance are painting and electrical and minor repairs.

The university staff is composed of professional maintenance employees hired directly by the school, yet the majority of the staff are contracted public employees. Sporadically, when a specific service is needed and the university employees do not have requisite knowledge, outsourced staff are hired to fulfill the stipulated demand.

Currently, the university has not yet presented a plan or maintenance program. The specific building maintenance strategies for buildings with metallic structures are under the responsibility of a particular

Fig. 3 Laboratory.
Source: Office Communication, UNIFEI, 2015 [17].

Fig. 4 Metal structures building, Itabira.
Source: Office Communication, UNIFEI, 2015 [17].

outsourced company. Periodically, there has been some kind of mapping to analyze the states, conditions and conservation of these buildings.

3.3 UFMG

The UFMG is the largest in the state of Minas Gerais and is one of the top five federal universities in Brazil. Like most universities, its origin is comprised of a fusion of several individual colleges dating back to the Brazilian colonial period.

In 1907, the University of Dentistry was created; four years later, the Schools of Medicine and Engineering were established along with the School of Pharmacy, now annexed to the Dentistry School. The Mechanics Institute (now called The "Technical College") and the Rectory were the first buildings erected in what is now the Pampulha Campus.

The campus was only effectively occupied by the university community in the 1960s with the construction of the buildings that house most academic units today. The buildings that are part of the main campus of UFMG with different building typologies include the ICEB (Institute of Sciences and Biology) and the building of the Service Square (Figs. 5 and 6).

The SIM (superintendent of infrastructure and maintenance) was established in January 2011, encompassing the Department of Construction, the Department of Maintenance and the purchasing and budget consulting. In October 2012, the newly created Department of Projects (DP-SIM) was incorporated into the SIM structure, responsible for Executive Projects Works of Reform and Small Service Projects, while purchases became the responsibility of the PRA (pro-rectory administration). The SIM performed approximately 50,000 maintenance operations in 2013 and has currently in its portfolio 350 projects.

Monthly reports are produced reflecting each kind of service (viz. building, hydraulic, electrical and equipment) performed on every unit in each of the UFMG campuses (i.e. Pampulha, Health, HC, ICA, Diamantina, Pedro Leopoldo Farms and Igarapé).

With the same objectives as those specified above, the Reform Monitoring System was created in order to fulfill reforms and small services. Using the Institutional

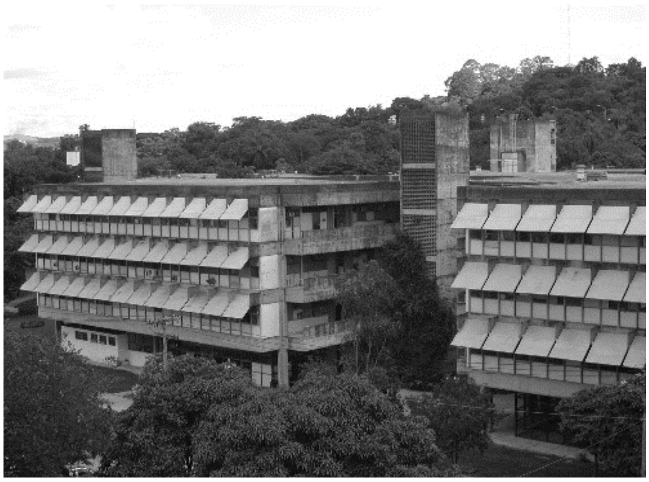

Fig. 5 ICEB.
Source: Foca Lisboa/UFMG, 2015 [18].

Fig. 6 Service square building.
Source: Foca Lisboa/UFMG, 2015 [18].

Development Project, all the filing sector material, approximately 50,000 documents, were scanned.

Moreover, a survey of the situation of all the buildings of the Campus Pampulha was performed. The results of this work were collected into a digital file with multiple entries, recorded on a CD-Rom containing the main pathologies, special equipment and as built of the buildings and green areas.

Outsourced services are only those that depend on specialized and skilled labor. More than half of the professionals involved in the maintenance service are outsourced. The systems of information or software used by UFMG for maintenance management are generated through general networks and spreadsheets.

4. Discussion

From the actions presented in Table 1, it is possible to compare the main maintenance management actions currently used by the three federal universities cited.

This comparison was carried out through the responses of interviews with those professionals involved in the maintenance of the buildings of the Federal Universities. The UFMG, perhaps because it is the largest university of the state and since it has the greatest budget volume, presents the most detailed maintenance management system with a survey of the conservation status of all its buildings, although it may already be out of date, but nevertheless containing an important amount of data and information capable of

Table 1 University management maintenance actions (continue).

Maintenance actions	UFOP	UNIFEI	UFMG
Plan or maintenance program	Not available	Not available	Not available
Professionals involved in maintaining	Large part of the professional framework of maintenance is now outsourced.	The professional staff of maintenance is composed of employees of the university and, mostly, by public employees.	In Demai there are currently 50 workers who are permanent staff and 150 outsourced employees.
Outsourced maintenance services	Only very specific services are external to the University's staff.	Outsourced services are surveillance, building cleaning, restaurants and various other services.	Maintenance/conservation lifts; Maintenance/conservation of energy generators; preventive/corrective maintenance of energy substation; preventive/corrective maintenance of fire hydrants; Maintenance/fire extinguishers recharge; Service.
			Painting/revitalization with supply of materials; Delivery services/tempered glass installation; plaster lining; PVC liner; drywall walls; vinyl flooring; Paviflex floor; stones, etc.
		Cleaning, restaurants and various other services	Maintenance/fire extinguishers recharge; Service Painting/revitalization with supply of materials; Delivery services/tempered glass installation; plaster lining; PVC liner; drywall walls; vinyl flooring; Paviflex floor; stones, etc.
Information systems used to manage	Electronic service request system and Excel spreadsheet	Virtual platform "Ocomon"—occurrences monitor and computer equipment inventory	For the O.S system (Service Orders): The system works via the UFMG network to request maintenance services. Excel worksheet is used for recording reform requests.
Building inspection—survey of the conservation status of buildings	Only in the Mining School building has a survey of the conservation status been carried out.	Eventually there is a gross evaluation of conditions, visual observation and cleaning operation.	In 2007, Demai created a PDI—Institutional Development Plan, whose objective was to make the survey of conditions and conservation status of all the buildings of the campus of UFMG. The project was completed in 2011.
Buildings with steel structure	Building of the School of Minas and the Medical School	Building 2 and Building José de Alencar	The Knowledge Center of the building is a metallic structure and glass façade. The façade of the administrative building of the Law School has a metal frame. The rectory building façade has a metal frame. The Complex Service Square is a metallic structure.
Specific maintenance actions for the buildings with metal structure	There are no budgetary questions.	Specific strategies with reference to the steel structures are in charge of a company from Itabira town.	There is no maintenance strategy for these buildings. The locksmiths and painters perform interventions periodically with the purpose of repairing and conserving the structures.
Distribution of maintenance between the existing buildings	The distribution follows the order of the requests sent, except for services that need priority.	The building maintenance staff ranks occurrences in order of need and importance, so it can be said that the distribution is centralized.	Routine maintenance services are requested by the General Services Sectors of the Units through the O.S (Service Orders). Reform services are requested by the directors of the Units to the Management Provost through e-mails or letters.

generating more effective and targeted interventions. Also, the same institution has outsourced maintenance services to a greater degree, and has detailed the outsourced service framework contemplated to the greatest extent. The only institution that presents in its professional institution itself all the work with the building maintenance services is the UNIFEI.

5. Conclusions

Within the comparison between the three federal universities of Minas Gerais, it can be said that the main management tool, i.e. the creation of a building maintenance plan or program guiding the activities and distributing their actions within a specific period of time, is lacking in each institution.

Another very significant issue that needs to be addressed is the lack of an effective database of the activities being carried out, together with a database of the current condition of the buildings.

The existing information system in universities today is limited only by the survey of demands or requests not being used as a management tool. The efficient management of maintenance and quality requires greater knowledge of the reality of the buildings and the actions or interventions that are performed.

In Brazil today, the outsourcing of the workforce is a reality and needs to be discussed further. In some interviews, professionals attributed the discontinuance of the services to the lack of commitment from the outsourced labor workers. Perhaps a more detailed survey of the outsourced teams would show whether this contention is a reality or not. Universities that have buildings with different construction typologies were chosen to determine which specific actions exist in the maintenance of each building. However, it is clear that there is no particular concern to share the role in actions for these typologies and buildings with metal structures, which often do not receive specific interventions. Perhaps this is not only a budgetary problem, but it also comes as a direct result of the lack of the aforementioned maintenance plan.

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Egyptianizing the Classical Approaches of Post-disaster Housing

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Abstract: This research is intended as a practical guide on how to custom-tailor post-disaster housing approaches to suit the countries in which they are implemented. Three classical approaches are chosen, discussed and analytically compared in order to unveil the shortcomings of their implementation in a country such as Egypt which is faced by technological, economic and time-related challenges in our current time. Strategies are synthesized to in order to overcome these challenges and enhance the prospect of implementing the approaches in the country. Finally, the research presents a series of recommendations which can guide the implementation of the strategically enhanced approaches while bearing reference to real-life challenges and opportunities.

Key words: Post-disaster housing, classical approaches, strategies, expediting implementation, integrating with governmental plans.

1. Introduction and Statement of Problem

In the aftermath of a disaster, local and state governments, in addition to charitable organizations, embark on several tasks to aid disaster-affected communities [1]. Different processes of sheltering and housing provision are employed through cycles of aid which extend from the "emergency response phase" (immediately after the strike of a disaster) to the stage of "post-disaster recovery" [2]. These processes include the provision of tents and imported/prefabricated design units. Also included is providing temporary housing and hazard-resistant structures [3].

In real-life, processes of post-disaster housing are implemented through a number of approaches. Among the classical (most used) approaches are: "Sheltering during Reconstruction-SDR", "Three-Stage Recovery-3SR" and "Two-Stage Recovery-2SR" [4]. Each of these approaches has its requirements and expected outcomes which render its implementation in Egypt a subject worthy of investigation especially in light of the difficulties which affront the country in our current times.

1.1 Research Aim, Objectives and Methodology

The main aim of this research is to custom-tailor classical approaches of post-disaster housing in order to be suited for implementation in Egypt. To this end, the first objective of the research is to investigate the modus operandi of these approaches. The ensuing objective is to understand the factors which influence the approaches' suitability for implementation in the country. The ultimate objective of the research is to synthesize strategies which can "Egyptianize" the approaches while enhancing the prospect of their successful implementation.

In order to fulfill its aim and objectives, the research subjects the three classical approaches (SDR, 3SR and 2SR) to a comparative analysis which bears reference to Egypt's current conditions. Consecutively, the research builds upon the results of the comparative analysis to inductively synthesize a number of strategies which address the real-life implementation of these approaches.

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2. Discussion of Procedure: Comparing Classical Approaches of Post-disaster Housing

The SDR approach (Fig. 1: left) stipulates that a disaster-affected community is moved into tents/host families as a primary “emergency response” after the strike of a disaster. The community is then offered temporary structures which have the ability to develop into permanent and more hazard-resistant structures. With the passage of time, the community is expected (and ideally: encouraged) to carry on improvements and modifications to the structures until reaching their final (permanent) state.

In similarity to the SDR approach, the 3SR approach (Fig. 1: middle) starts by moving the affected communities after the onset of a disaster into tents/ host families. However, the community is not provided in the 3SR approach with temporary structures which have the ability to develop into a permanent house. Instead, the community relocates in a transitional shelter where people stay for a period of time until the construction of their prospected permanent houses is finished.

On another front the 2SR approach (Fig. 1: right) strives to eliminate transitional phases of housing provision in order for people to be directly moved from emergency shelters to permanent houses. This usually means designing and fostering emergency shelters with the ability of hosting disaster-affected communities for long periods of time. This approach also calls for promoting and expediting the construction of permanent houses [5].

In order to ensure subjectivity, this research comparatively analyzes the SDR, 3SR and 2SR approaches while bearing reference to a number of criteria which represent serious challenges to Egypt in our current times. These criteria are: lack of technological advances, inability to sustain high costs, urban sprawl, time consumption and the difficulty of promoting advanced logistics. Results of the comparative analysis are summarized in Table1.

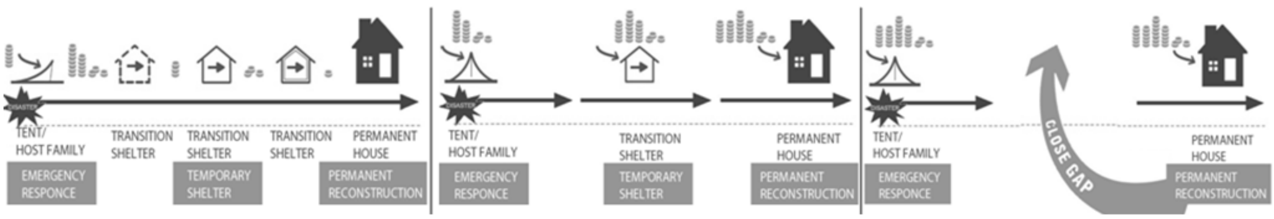

Fig. 1 Left: “Sheltering during reconstruction-SDR” approach. Middle: “Three stage recovery-3SR” approach. Right: “Two stage recovery-2SR” approach [4].

Table 1 Results of the comparative analysis.

FACTORS / APPROACHES	APPROACH 1	APPROACH 2	APPROACH 3
TECHNOLOGY ADVANCES	✓	✓	✓
HIGH COST	✓	✓	✓
URBAN SPRAWL		✓	
ADVANCED LOGISTICS	✓		
TIME CONSUMING	✓	✓	

Post-disaster housing approaches, which stipulate transitional phases, have been frequently criticized due to a number of problems [3]. A major problem for the SDR and 3SR approaches is the apparent distinction, in industrialized countries, between temporary and permanent housing which cannot be readily applied to developing countries where a permanent house may be cheaper and built in less time than an imported sheltering or housing unit. The term “temporary” has frequently been used where a shelter or house has been designed for a short life-span, but owing to its cost of replacement, it inevitably becomes permanent [6]. Temporary shelters and houses have a tendency to remain for much longer than anticipated because the flow of international aid to build permanent housing diminishes over time. Accordingly, if there are no long-term plans for permanency, temporary shelters and houses will become permanent ones. The unplanned evolution of temporary shelters and houses into permanent houses frequently leads to uncontrolled urban development (i.e. urban sprawl) or even worse: shanty towns. There is also the additional problem of long time periods which span the interval between the strike of a disaster and the provision of a permanent house; the thing which slows the “post-disaster recovery” process in general. Moreover, post-disaster permanent houses are not usually designed for long term accommodation and might thus result in a redundant quality of living for their inhabitants. Another problem which affronts the implementation of SDR and 3SR approaches in Egypt is the huge monetary expense needed to finance the several inherent transitional phases. These transitional phases also necessitate advanced logistics to transport the various sheltering and housing components involved (i.e. tents, transitional shelters and temporary houses) to their designated locations.

On another front, the 2SR approach is not challenged by problems of long time spans or by the drawbacks of transitional phases. However, this approach calls for huge monetary expenses and technological advances for designing structures that are anticipated to last long and for speeding up the permanent construction processes. Apparently, these two important factors are considered shortcomings in the case of Egypt.

3. Strategies for Enhancing the Approaches

Despite their apparent shortcomings, the SDR and 3SR approaches have frequently proven themselves indispensable in disaster situations. Accordingly, this research endeavors to synthesize strategies which would “Egyptianize” these approaches through enhancing the prospect of their successful implementation in the country. From comparing these approaches, it can be deduced that their inherent transitional phases accrue long time spans and expenses. Hence, strategies which can expedite these approaches are a logical counter-move against delays and amassed costs.

Expediting the SDR and 3SR approaches opens the door for investigating how to reduce delays in post-disaster housing approaches. Accordingly, synthesizing a strategy which can close the gap between the “emergency response phase” and the permanent housing stage is essential to enhance the 2SR approach. However, in order to succeed, this strategy should be aware of the extended lifetime of the emergency shelters as well as the efforts and expenses required to promote permanent housing construction.

3.1 Expediting the SDR and 3SR Approaches

One way of expediting the SDR approach is using modular box units for sheltering and housing. These units should be ready and kept in storage in preparedness to a disaster situation so that once the disaster strikes; the affected community can be easily accommodated. Modular box unit systems are three dimensional spatial elements formed commonly by the combination of wall and floor panels [7]. These systems, constituting an advancement of heavy and light-weight panel systems, can achieve a high degree of completion through factory manufacturing (i.e. the prefabrication of temporary shelters and houses). However, occupants are demanded to further develop the units in various ways until they turn into their permanent houses. Novel ideas and innovative designs of box units can be beneficial to the attempt to expedite the SDR approach. For example, the "GA (Ganti + Associates)" Design firm has won an international ideas competition with a radical shipping container skyscraper that was envisioned to provide temporary housing in Mumbai's overpopulated Dharavi Slum [8].

On a relatively different note, the attempt to expedite the 3SR approach should be aware of the fact that this approach involves consecutive processes of relocation. These relocations are sometimes perceived as an inherent aspect of "post-disaster recovery" stages for one or more of the following reasons: (1) People have already been displaced by the disaster; (2) Their current location is judged to be uninhabitable; or (3) Relocation is considered the best option to reduce vulnerability to the risk of future disasters. Relocation of disaster-affected communities requires well-planned and adequately financed programs that include land-for-land exchange, employment generation, ensured food security, and improved access to health services, transportation to jobs, restoration of common properties as well as support for community and economic development.

Expediting the relocation processes (which are inherent to the 3SR approach) can be achieved through "settling-in" abandoned spaces. The idea is to divide up these spaces while transforming them into settlements which can host disaster-affected communities. For example, Levitt Bernstein was announced winner of the open international HOME competition for his intriguing proposal to create pop-up housing in unused garages on London's existing housing estates [9]. In another example, Berlin officials decided in 2015 to convert the abandoned hangers in the Tempelhof airport, Germany into a settlement for refugees. The hangers were divided up into administrative and housing zones which would satisfy the living needs of the people [10].

3.2 Reducing Delays in the 2SR Approach

The attempt to close the gap between the "emergency response phase" and the permanent housing stage (in the 2SR approach) would be severely faced in Egypt by the common lack of integration between disaster management plans and traditional urban development schemes (i.e. plans to establish neighborhoods, districts and towns which are typically top-down implemented by the government). Accordingly this research strives to synthesize a strategy which would make post-disaster housing an integral part of governmental development plans.

The strategy (illustrated in Fig. 2) suggests refinements to a typical development scheme which would be prepared by governmental authorities in Egypt to establish a neighborhood. For the sake of argument, the establishment of the neighborhood is proposed to start at the year 2025 and to be completed by the year 2030. The strategy, synthesized in this research, commences by proposing the erection of a building in the year 2017 at the centre of the neighborhood in the exact location which is already preplanned by the government. During the period between 2017 and 2025 (that is to say: before actually starting to establish the neighborhood), the building can be used as a multi-purpose facility to generate income. By the year 2025, and as the establishment of the neighborhood commences, the building would be turned into an administrative/community center. This center would host activities which are essential for inaugurating the establishment of the neighborhood (for example administrative tasks and meetings with community members). By the time the neighborhood is completely established in the year 2030, the building would assume the original function for which it was predestined by the government: act as the neighborhood center.

In order to integrate disaster management plans within this development scheme, the strategy presents

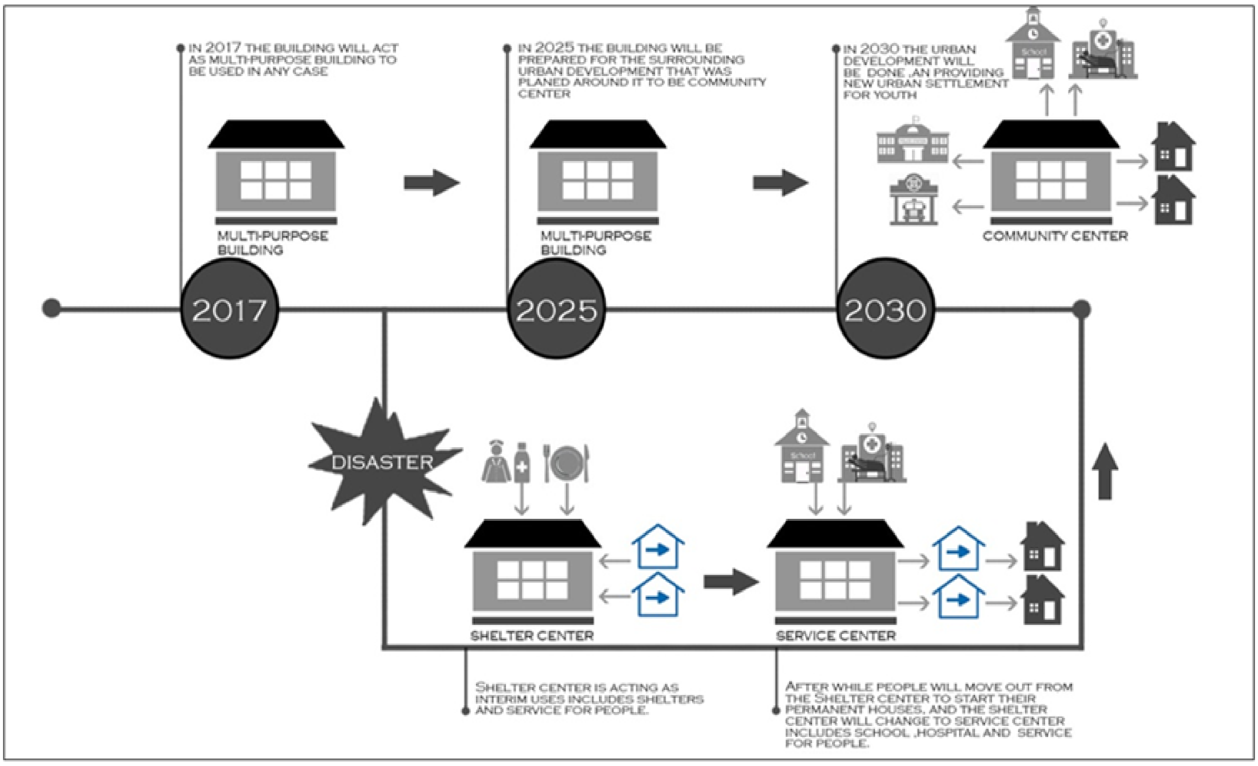

Fig. 2 Strategy for integrating post-disaster housing activities within governmental urban development schemes.

an alternative scenario which involves the strike of a disaster. If a disaster incidence would strike, for instance, in the year 2020, the building (which by this time would be in use as a multi-purpose building in accordance to its original development route) would be turned into an emergency shelter to host disaster-affected communities. With the passage of time, the building would be transformed into a service centre to help sustain "post-disaster recovery" activities (for example: people going back to their old jobs or starting new careers). As the year 2025 approaches, the disaster service centre would be rechanneled into becoming a community centre in order for the disaster recovery scenario to integrally coincide with the original development route. From this point forwards, the building would be developed into a community centre for the affected-communities which would now become the new occupants of the neighborhood.

4. Conclusions: Recommendations for Implementing Post-disaster Housing Approaches in Egypt

The use of imported or factory-manufactured (prefabricated) box units in Egypt would face considerable difficulties including cost insufficiency and the absence of the technological capabilities needed for utilization. Should this strategy be used to expedite the SDR in a developing country such as Egypt, the units' cost should be kept relatively lower than that of a permanent house which might be constructed in less time and cheaper than an imported or prefabricated unit. One way of doing this is using low-tech techniques and local materials which allow the units to be manufactured in-situ. These refinements to the original strategy might also compensate for the lack of skilled labor, heavy-duty equipment, precision measurement and handling for in-position placement. In-situ construction of units allows a response team (composed of expertise and locals) to rapidly deliver and set up emergency housing faster than most other approaches which depend on technically-demanding installations typical to factory-manufacturing. Moreover, in-situ construction would decrease the need for transporting the units to their designated locations (for examples on vehicular trailers or train carts). On a related note, post-disaster housing units need to be designed in a way which can result in a variety of configurations while providing their occupants with enough flexibility to apply changes to their homes. The units should be also allowed to connect together to provide larger living quarters.

The processes of relocation, inherent to the 3SR approach, are associated with cancerous growth of slums particularly in the fast growing cities of Asia and Africa; the thing which poses a challenge for providing adequate basic services and infrastructure. This challenge is central to the economic performance of cities, and their ability to provide a minimum quality of life to their citizens. To this end, the attempt to expedite the 3SR approach by transforming abandoned spaces into settlements should be aware of the resultant density and quality of living.

Establishing settlements outside of cities' boundaries is a counter-measure against inner-city urban sprawl because these newly occupied spaces can be nuclei for future development.

The attempt to close the gap between "emergency response phase" and the permanent housing stage in the 2SR approach should ideally be implemented with the following recommendations in mind:

- Encouraging the participation of affected communities in critical decisions concerning relocation and implementation;
- Establishing channels of communication with target groups to resolve difficulties and challenges;
- Grouping people from similar same communities together in a new settlement;
- Designing houses, settlement layouts and community facilities to suit the community of life;
- Assessing disaster-induced risks to make sure that these risks cannot be mitigated in the old location, while the community can be assured the absence of these risks in the new settlement.

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